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Great Smoky Mountains National Park Hard Mast Survey: An Evaluation of the Current Survey, Analysis of Past Data, and Discussion of Alternatives for Future Surveys

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GREAT SMOKY MOUNTAINS NATIONAL PARK HARD MAST SURVEY: AN EVALUATION OF THE CURRENT SURVEY, ANALYSIS OF PAST DATA, AND DISCUSSION OF ALTERNATIVES FOR FUTURE SURVEYS

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NATIONAL PARK SERVICE - Southeast Region

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ABSTRACT

Measuring hard mast crop size is important to management in Great Smoky Mountains National Park (GRSM) for three reasons: (1) mast availability influences the winter condition, survivorship, and reproductive potential of the exotic pest animal, the European wild hog, and a variety of native animals (including the black bear); (2) evidence suggests that the most effective trapping programs for wild hogs are carried out in years of mast failure; and (3) mast availability is used as a parameter in the hog population models that are currently being developed (these models are also helping to address the question concerning competition between European wild hogs and native animals for the hard mast crop). With the loss of American chestnut, the most important hard mast producers in GRSM are currently species of oak. Wide year-to-year fluctuations in mast crop size have been experienced.

A hard mast survey has been carried out by the GRSM Resources Management Division since 1979. This report represents an analysis of the past data and assesses the mast survey sampling regime. Hard mast surveys in GRSM use a stratified random sample, in which the sample stratification consists of an even geographic spread of sample routes and an even spacing of sample stations along those routes. At each sampling station, trees are chosen within the constraints of the selected criteria. The sample stratification provides an adequate sample of relative mast crop size within broad species groups, but it mitigates against valid species-specific data (for example, site quality and sample size are uncontrolled. The index derived from these data is a dimensionless scalar (the mast index) ranging from 0 to 10. While absolute measurements (e.g., kg per ha or calories per ha) would be more ecologically meaningful, current use of the data does not justify the more intensive work required for such data. We recommend several amendments to sampling procedures (use of a maximum diameter limit for sample trees, redesign of sampling sheets) and propose a new method for calculating the mast index. An important suggestion concerned timing of the mast survey. Past data, notes on field data sheets, the observer bias study, and a literature review suggested that the surveys were carried out too late in the year. In the future, surveys should be completed by mid- to late August. A schedule for timely data analysis and reporting is also suggested. A mast quality assessment using seed traps would increase the value of present data. An observer bias study suggested that observers did not make significantly different estimates of tree mast; however, absolute values of mast were low at the time of the 1983 survey, and the bias study should be repeated in future surveys.

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INTRODUCTION

Since 1979, the Resources Management staff of Great Smoky Mountains National Park (GRSM) has conducted a parkwide hard mast survey. The purpose of this survey is to provide information for managers and researchers who work in wildlife management areas, particularly with regard to the native black bear and the exotic pest, the European wild hog. Mast survey data have also been shared with biologists from nearby state wildlife management areas (Whitehead 1980). The study presented in this report was undertaken to evaluate the current GRSM hard mast survey program, to assess whether this program meets management needs, and to make recommendations for an optimum mast survey regime. This report is divided into four sections: a literature review, methods (covering the 1979-1983 field surveys, our 1983 observer bias study, and data analysis), results, and discussion. We use the last section to consider alternatives for the future hard mast survey programs.

Movement of hard mast crop size is important to management in GRSM because of the influence of mast availability on winter condition, survivorship, and reproductive potential of wildlife populations (Goodrum et al. 1971), including those of the European wild hog (Matschke 1964, Scott and Pelton 1975). Year to year hog population fluctions of a least 20 percent and perhaps as much as 60 percent are suspected; the most frequently cited cause of these fluctuations is hard mast availability (e.g., Singer and Ackerman 1981). During the fall, hard mast can exceed 80 percent of total wild hog stomach contents (Henry and Conley 1972). Competition for hard mast may occur between the wild hog and native animals, particularly during years of mast failure (Baker 1944, Henry and Conley 1972), but the extent and importance of this competition are unknown. Mast crop size influences the movements and impacts of the European wild hog (Howe and Bratton 1976; Singer et al. 1981; Bratton et al. 1982). Hogs ranged greater distances during years of mast failure, with some animals returning to high elevation rooting habitats in winter (in years with abundant mast, hogs moved to high elevations in the late winter or early spring. Information on mast crop size is needed to relate GRSM hog rooting indices to hog population trends because rooting impacts fluctuate with mast crop size as well as with hog population size. Data on hard mast crops is used to prioritize management efforts; during years of mast failure, trapping with corn mash baits is more effective than during years of mast abundance, when shooting programs may be more efficient. Finally, data on hard mast are being used in the development of hog population models.

Major hard mast producing species in GRSM include five species of hickory, (*Carya* species), two species of walnut (*Juglans nigra* and *Juglans cinerea*), beech

(Fagus grandifolia), and 10 species of oak (Quercus species) (Table 1; nomenclature follows White 1982). The loss of the American chestnut (Castanea dentata) in the last 50 years brought a profound change to hard mast availability in GRSM; American chestnut was a widely distributed dominant tree in the park and was a consistent and heavy bearer of nut crops. The loss of this species emphasizes the importance of the conspicuous year to year fluctuation in the remaining species, especially in the oaks. Buckeye (Aesculus octandra) produces a nut which is toxic to humans; this species was not included in the GRSM hard mast survey nor in any published literature we saw, although buckeyes are consumed by squirrels in the park (Stupka 1964). Nut producing shrub species (e.g., Corylus americana) are also generally ignored in the literature, presumably because of their low total production compared to trees. Acorns (Quercus species) are by far the most important of the hard mast food sources (Strickland 1972). The oaks are divided into two groups based on seed development. In the white oak group (Subgenus Lepidobalanus), seed development begins about one month after pollination, and the seed matures in one growing season. In the red oak group (Subgenus Erythrobalanus), seed development begins about 13 months after pollination, and seed maturation requires two growing seasons.

There is currently no all-park vegetation map. Hence there is no parkwide estimate of the area of dominance by the hard mast producers in GRSM. This means that mast surveys are generally used in a qualitative and relative sense. We cannot extrapolate the data to total crop size. The Science Division, GRSM, currently is using remote sensing data to create a modern park vegetation map. That map will make possible the calculation of mast-bearing area in the park; this application will be facilitated because the vegetation data base is being developed in a computerized format.

LITERATURE REVIEW

Definition of "Hard Mast"

Hard mast is a calorie-rich food that is used from late summer through winter and into the spring, depending on availability. The term "mast" has been widely used in America since pioneer days (Sharp 1958). "Mast fruiting" has been described as the periodic and synchronous production of large seed crops by tree populations (Sork 1983). Sharp (1958) used a narrow definition, equating mast with all fruits used as food by domestic or wild animals. Hard mast consists of nut crops, whereas soft mast consists of fleshy fruit crops.

Table 1. Major Hard Mast Trees of GRSM.

Code	Common Name	Scientific Name
	WHITE OAKS	
QRCALB	White Oak	Quercus alba
QRCPRN	Chestnut Oak	Quercus prinus
QRCSTL	Post Oak	Quercus stellata
QRCMHL	Chinkapin Oak	Quercus muehlenbergii
	RED OAKS	
QRCRBR	Northern Red Oak	Quercus rubra
QRCFLC	Southern Red Oak	Quercus falcata
QRCCCC	Scarlet Oak	Quercus coccinea
QRCVLT	Black Oak	Quercus velutina
QRCIMB	Shingle Oak	Quercus imbricaria
QRCMRL	Blackjack Oak	Quercus marilandica
QRCRED	Unidentified Red Oaks	
	HICKORIES	
CRY	Unidentified Hickory	
CRYCRD	Bitternut Hickory	Carya cordiformis
CRYTMN	Mockernut Hickory	Carya tomentosa
CRYOVT	Shagbark Hickory	Carya ovata
CRYGLB	Pignut Hickory	Carya glabra
CRYOVL	Sweet Pignut Hickory	Carya ovalis
CRYPLL	Sand Hickory	Carya pallida
	WALNUT	
JGL	Unidentified Walnut	
JGLNGR	Black Walnut	Juglans nigra
JGLCNR	Butternut	Juglans cinerea
	BEECH	
FGSGRN	Beech	Fagus grandifolia

Mast Surveying Methods

Seed Traps. Several different kinds of devices for catching seeds have been used. Usually the trap is a shallow box with mesh netting stretched across the top to allow seeds to pass but to keep wildlife out. Seed traps have the following advantages: Traps reduce labor over ground counts, seeds can be concentrated using a funnel-shaped trap, and traps lessen wildlife impacts on seeds that occur with ground counts. Nixon et al. (1980) used two 125-liter steel barrels located at each study tree. In a 13-year study, McQuilken and Musbach (1977) used 25 individual bushel basket seed traps on each of 36 0.2-ha 0.49-acre) plots. (NOTE: Where English measurements were used in original publication , we will cite metric and English measurements together.) Strickland (1972) used two 4.1-m^2 (0.1-milacre) traps under each selected mast tree. Goodrum et al. (1971) reported using seed traps 10.2 m^2 (0.25 milacre) in size and tending the traps weekly to collect the seeds. Inverted pyramidal canvas seed traps with a 1-m^2 (10.9-sq ft) collection area were used by Gysel (1971) Seed production was estimated by Beck and Olson (1968) by catching acorns in 4.1-m^2 0.1-milacre) cardboard traps, 24 to a plot.

There are several problems with mast estimates when seed traps are used. Several sources caution that counting the number of seeds that fall to the ground below specific trees may result in a significant underestimation of total acorn crop. Wind may whip seeds considerable distances from sample trees (McQuilken and Musbach 1977). Gysel (1956) reported that the number of acorns that are deflected from traps was large enough to make data useless. If seed traps are not serviced regularly, leaves and twigs may cover netting so acorns remain on the surface of the trap and are therefore available to animals. Also, a large number of seeds are removed directly from the trees by arboreal feeders (McQuilken and Musbach 1977). Finally, small rodents have been reported to use some seed traps to store nuts and acorns (McQuilken and Musbach 1977).

Tipton and Otto (1979) maintained that seed traps were not feasible as the sole mast survey method for GRSM. Thirty 10.2-m^2 (0.25-milacre) steel seed traps were constructed for catching mast. During the fall collection period, seven of the traps were mangled or destroyed by bears. Other traps were removed or dumped, presumably by wildlife. Those traps which remained intact were reported to collect mast adequately. Use of traps in GRSM is feasible for specific study sites and purposes (e.g., for calibrating absolute seed fall and seed soundness) but could never constitute a whole park survey technique.

Ground Counts. Counting seeds on the ground is a simple method of estimating mast productivity. Dalke (1953) established .04-ha (0.1-acre) plots every 11 m (1-chain) interval for 10 km (5.6 mi). Cypert and Webster (1948) collected acorns from triangular sample plots covering approximately 10 percent of a tree's crown area.

While ground counts require no specialized equipment, the method is time-consuming. The amount of crop damaged or removed by wildlife is unknown in such surveys (hence, introducing error in the estimate of total crop size). Using empty acorn caps on the ground is not accurate because caps often do not fall for many months (Gysel 1956). Tipton and Otto (1979) claimed that annual mast yields in GRSM could not be feasibly estimated through ground counts because analysis of plots was greatly complicated by dense ground vegetation, variable litter depth, and rugged slopes. However, ground counts could be used on selected plots, with periodic remeasurement from fall to winter, in order to track acorn availability to hogs. Gysel (1956) used analysis of variance to test mean differences of seed traps and ground count data. With the assumption that both methods represented random samples, no significant difference was indicated at the 5 percent level.

Tree Counts. The most accurate determination of the number of seeds on a tree can be made by direct count before seed fall and heavy wildlife use occur. Complete counts for whole canopy trees are difficult and laborious. Representative sampling of subareas within the crowns of random trees is more efficient (Gysel 1956).

A mast survey in the Tellico Wildlife Management Area was made on existing road systems with observation stops every 0.8 km (0.5 mi). At these stops, mast trees were observed with binoculars, and the fruit production was recorded (Henry and Conley 1972). Whitehead (1969, 1980) surveyed eight trees along each of the Tellico routes, counted the seeds on five random 90-cm (3-ft) limbs, and estimated the percent of canopy cover with acorns. According to Tipton and Otto (1979), Whitehead's unpublished survey method was the easiest and the most applicable to the topography of GRSM. This is the method presently used by Resources Management of GRSM and by the Tennessee Wildlife Resource Agency for their annual mast survey (Whitehead 1980). In Pennsylvania, Sharp (1958) surveyed random mast trees and counted acorns on the terminal 60 cm (24 inches) of random branches in the productive part of the tree crown.

A special problem in terms of tree crown based counts occurs for species which have variable numbers of "nuts" per fruit. In the southern Appalachians, beech

is in this category. Ground counts of nuts give higher numbers than crown counts of fruits.

Seed Quality Determination. During seed trap and ground count surveys, mast can be collected and examined for seed quality. The simplest analysis for acorn quality is to divide acorns into two categories: sound and damaged (Gysel 1956). In Sork's (1983) three-year study of *Carya glabra*, nuts were opened and classified as infested, aborted, or viable. Some studies have classified seeds in four groups: well-developed and sound, well-developed and damaged by animals, well-developed with insect damage, and imperfectly developed or aborted (Nixon et al. 1980; McQuilken and Musbach 1977; Beck and Olson 1968; Downs 1944; Downs and McQuilken 1944). Gysel (1971) divided beechnuts into five categories: sound, damaged by insects, utilized by animals, decomposed, and incomplete. Strickland (1972) placed acorns into the five classes: immature and sound, immature and insect infested, sound and mature, mature with insect damage, and mature with damage by aboreal feeders. Gysel (1957) tallied acorns according to categories of sound, damaged by insects, damaged by animals, malformed by fungi or bacteria, and malformed due to undetermined physiological changes.

Mast Indices

Mast surveys usually provide quantitative data on specific plots or trees. Most often, these data are then used to compute an overall mast index. This index is a dimensionless scalar which most often ranges from 0 (for mast failure) to 10 (for a maximum mast crop). Unfortunately, there is little discussion in the open literature on these mast indices, including the one used in GRSM (Whitehead 1980).

Some mast surveys ignore quantitative data altogether and simply assign mast ratings by general field observation. Mast surveys of the Tellico Wildlife Management Area, Tennessee, area were made with observation stops every 0.8 km (0.5 mi). At the stops, oak, hickory, and beech trees were observed with binoculars, and fruit production was recorded by species, using the classification of "none," "few," "fair," and "abundant" (Henry and Conley 1972).

Uhlig and Wilson (1952) attempted to quantify such subjective mast observations. Participants were asked to describe available fruit of a species: abundant, common, or scarce. An index of mast condition for each species was derived by calculating the percent of total surveyors reporting each category. For each species, the percent "abundant" was multiplied by 100. The percent "common" was multiplied by 50, and the percent "scarce" was multiplied by 0. The

species index was the sum of these three numbers. In order to get an overall mast index, the mast species were divided into two groups: canopy and understory. The following formula was published by Uhlig and Wilson (1952) for computing a mast index for these two groups:

$$\text{Group Index} = \frac{A(n) + B(n) + C(n) + \ldots}{n}$$

where:

A, B, C, etc., indicate indices for each species in the group

and

n = Number of observers reporting on the individual species

This equation is confusing as published in Uhlig and Wilson (1952). The "n" in the numerator and denominator represent different values. We correct this equation to:

$$\text{Group Index} = \frac{A(n_i) + B(n_j) + C(n_k) + \ldots}{\Sigma n}$$

where n_i is the number of the ith species in the group.

Sork's (1983) equation to estimate hickory crop size is an objective measure of productivity using ground count surveying techniques:

$$T = \sum_{t=1} F_t = \Sigma[f_t \ (1 + k \ (r_{t-1}/f_{t-1}))]$$

where

T - estimates total number of nuts produced by each hickory species

a - number of trees examined for each species

F_t-the estimated number of nuts that fell on the ground between week t and week t-1

f_t-the number of newly fallen nuts found on week t

r_t-the number of nuts found at week t but removed by week t+1

k - proportion of the week that the average nut remains on the ground before being removed

The method has several disadvantages as an all-park survey technique. First, the number of seeds lost to aboreal feeders is not quantified. Second, the technique is labor intensive because it requires someone to check the monitored quadrats weekly. A final problem is that the method only estimates crop size but does not evaluate crop quality. This last disadvantage occurs also in the tree crown surveys.

Sharp (1958) provided a mast index that is based on quantitative data. Ten trees of each oak species are randomly selected along each survey route. The

number of acorns on the terminal 60 cm (24 inches) of selected branches are then counted. A branch tip producing 32 or more acorns for red oak species and 24 or more acorns for white oak species is rated a 100 percent yield. The following categorical rating provides a mast index for each tree.

Fruiting Rank	Proportion of Maximum	Mast Index
Bumper	76-100 %	5
Good	51-75 %	4
Fair	25-75 %	3
Poor	10-25 %	2
Trace	10 %	1
None	No fruit	0

A species-specific index can be calculated by multiplying each different index rating by the number of trees observed, adding the products, and computing an average. Putting Sharp's explanation of his mast index into a formula gives the following equation:

$$\text{Species Index} = 5(n_5) + 4(n_4) + 3(n_3) + 2(n_2) + 1(n_1) + 0(n_o)$$

where:

n_o to n_5 are the numbers of trees observed for the species in each of the six mast abundance categories.

The Tennessee Wildlife Resource Agency and GRSM Resources Management Division use the mast survey index of Whitehead (1969, 1980). Singer and Ackerman's (1981) claim that Whitehead's field method was a modification of Sharp (1958) does not seem to be correct (see below).

The Whitehead index requires three different observations of acorn production: percent of crown producing acorns, percent of twigs in the productive crown that bear acorns, and the average number of acorns per productive twig. A sample form was provided for index calculation (Appendix A, Table A-1). Whitehead (1969) calculates the index as follows:

> The three criteria observed are dot tallied for each tree examined. The formula used for obtaining standardized numerical ratings follows. First, each of the three horizontal columns are totaled. The total number in each column is the number of trees examined, and the total of each of the three columns should be the same. Second, all of the dots in each of the five vertical columns are totaled. Third, take the total in the first vertical column and multiply it by zero (which always gives zero). Then multiply the second column by one, multiply the third column by two, the fourth column by three, and multiply the fifth column by four. Add the multiplied totals and divide this grand total by the number of trees. This will always yield a number between zero and ten, which is the oak mast numerical rating....

> ...when the numerical rating is between zero and 2.5, the acorn crop quality is judged to be poor; between 2.6 and 4.5, fair; between 4.6 and 6.5, medium; between 6.6 and 8.5, good; and when 8.6 or higher, was judged to be excellent.

Since this is the index used at GRSM, we present further details in the methods section. Whitehead (1980) presented an equation based on the dot tally method. This equation contains errors as printed and several unexplained fitted constants. We were unable to obtain a fuller explanation of this equation. Hence we based our analyses on equations we derived from the verbal description of the dot tally method (see Methods section of this report).

Whitehead (1969, 1980) and Tennessee Wildlife Resources Agency (1983) have published mast index data based on the Whitehead method. Whitehead (1969) presented tabular summaries of data from oak trees that had been surveyed for the mast index and then felled. Total numbers of acorns present were counted on the felled trees. Using weight relationships found in the literature, Whitehead (1969) was then able to translate the mast index scalar into an approximate absolute yield, expressed in pounds per square foot of tree basal area. He also presented tabular data giving the approximate yield (in pounds) per tree corresponding to mast scalar values. Unfortunately, Whitehead has not published his full data set nor described in detail how the tabular data was constructed. This makes an evaluation of the availability of this data set to GRSM impossible at this time.

Factors Affecting Productivity:

Little is known about beechnut (*Fagus grandifolia*) production. In a 10-year study, Gysel (1971) found no tree that was either a high or low producer every year but instead found that large crops occur at two to four year intervals.

Hickory seed production has also been found to be variable. Sork (1983), in a 3-year study of pignut hickory (*Carya glabra*), found year to year variation in seed production as well as synchronous fluctuation among individuals. Nixon et al. (1980) suspected that variable seed yields are the rule for most hickory species due to genetic differences among individuals, a tendency to produce fewer seeds the year after above-average seed production, and the influence of weather. However, there have been no specific studies of factors affecting hickory productivity.

Acorn crops are extremely variable from tree to tree, from species to species, and location to location (Olson and Boyce 1971, Beck and Olson 1968). In a

14-year study, some individual trees were inherently copious producers while others in the same stand produced no acorns or only a light crop (Sharp and Sprague 1967). White oak group species are notorious in this respect, and some trees do not bear acorns even in a very productive year (Sharp 1958). Gysel (1956) found that acorn production was highly variable and this variability is related to many factors, including specific species, age of tree, crown vigor, site quality, exposure, and weather.

Age. Acorn yields increase as trees mature. Yields tend to be largest in age classes from 40 to 99 years. Older trees may have dead portions in their crowns, resulting in decreased acorn yields (Goodrum et al. 1971).

Diameter. Acorn yields increase with increasing larger bole size in a linear relationship (Goodrum et al. 1971). Not only did production increase with larger diameters, but also a greater percentage of larger trees produced acorns. Downs (1944) reported that the average number of well-developed acorns increased as the diameter increased for *Quercus prinus*, *Q. velutina*, and *Q. coccinea*. Both *Q. alba* and *Q. rubra* had increased acorn productivity until they reached 71 cm (28 inches) dbh but then had declining seed crops.

For hickory species, Nixon et al. (1971) found that diameter accounted for a significant amount of the variance in sound nut production in *Carya ovata* and approached significance in *C. glabra* and *C. tomentosa*. In all cases, production increased with diameter.

Crown Size. Acorn yields also increased with increased crown radius (Goodrum et al. 1971; Gysel 1956; Downs and McQuilken 1944). Gysel (1956) observed that intensity of acorn production of a tree was up to 11 times greater in the portion of the crown exposed to full sunlight.

Climatic Factors. In a review of the oak mast literature, Olson and Boyce (1971) concluded that various environmental factors, such as wind, late frost, prolonged rain, relative humidity, and temperature affect the opening and closing of anthers, dissemination of pollen, and hence acorn production. However, during a 14-year study in Pennsylvania, Sharp and Sprague (1967) found that wind, precipitation, relative humidity, and vapor pressure deficits did not significantly influence acorn yields.

The only climatic factor that seems to predictably affect mast productivity is spring temperature. In a West Virginia study, Uhlig and Wilson (1952) found a correlation between the lowest spring temperature and mast indices. In a Pennsylvania study, Sharp and Sprague (1967) found that spring air temperature

strongly affected acorn yields. Good white oak acorn crops occurred in years when a warm 10-day period occurred late in April (average night-time air temperature of 55-60°F, 13-16°C), followed by cooler periods in early May (night-time mean temperature of 45-50°F, 7-10°C). During years when April remained cool and was followed by warm days and nights in May, acorn production was poor. The influence of temperature on acorn productivity was also found in a study conducted in Louisiana and Texas (Goodrum et al. 1971). Low temperatures of 25°F (-4°C) were reported during late March, a time when oaks bloomed. Limited white oak group yields occurred that year, and limited red oak group yields were recorded for the following year (Goodrum et al. 1971). A study done in the Tellico Wildlife Management Area, Tennessee, reported that an excellent _Quercus rubra_ crop of 1971 was associated with the spring 1970 temperature regime: rapidly rising temperatures in early and mid-April were followed by a cooling trend in late April and early May. The poor white oak year of 1971 was associated with lower April temperatures and a late frost in May (Strickland 1972).

While flower development in the hickories is similar to that in oaks (emergence of pistillate flowers occurs after male catkins emerge), not enough data is available to determine if above-average temperatures in preflowering stages, followed by below-average temperatures, is necessary for high nut yields. In a southeast Ohio study, Nixon et al. (1980) found a positive correlation between number of trees producing sound seed and the mean temperature for May 1-10.

Site Quality. Site quality seems to influence mast yield. Gysel (1957) studied acorn production on sites classified as good (Miami silt loam with _Q. rubra_ and _Q. alba_ as dominants and Fox sandy loam with _Q. alba_ and _Q. velutina_) and poor (Grayling sand with _Q. velutina_). The crown area of trees was greatest in the good sites and smallest in the poor sites. The good sites showed the highest acorn productivity as measured by sound acorn weight per unit crown area.

Quality of site can also have an important effect on soft mast production. Species growing on loamy sand were smaller in height and crown diameter versus those grown on sandy loams. The average fruit of honeysuckle (_Lonicera tartarica_) was three times greater on sandy loam. Fruit production of Russian olive (_Elaeagnus angustifolia_) was 10 times greater on loam (Gysel and Lemmien 1964).

Seed Condition

Seed condition is as important as quantity and is equally variable. Birds and squirrels damage much of the mast crop, as do insects such as nut weevils (e.g., *Curculio* spp.), weevils (e.g., *Contrachelus* spp.), dipterans (e.g., *Dasineura* spp.), and moths (e.g., *Valentinia glanullella*) (Strickland 1972, Olson and Boyce 1971, Downs and McQuilken 1944). However, as the total number of seeds increases, the percentage of seeds that develop fully also increases (Beck and Olson 1968, Downs and McQuilken 1944). Various authors have reported the percentage of sound mature acorns to be expected for a mast yield. Strickland (1972) recorded 25.0 percent of *Quercus alba* acorns and 51.8 percent of *Q. rubra* acorns were sound and mature. In an 18-year study, *Q. prinus* had 94 percent, *Q. alba* had 91 percent, *Q. stellata* had 72 percent, *Q. marilandica* had 73 percent, *Q. incana* had 74 percent, *Q. nigra* had 70 percent, and *Q. falcata* had 82 percent sound acorns (Goodrum et al. 1971). In a 14-year study, *Q. palustris* was reported to average 44 percent of yield to be sound and developed (McQuilken and Musbach 1977). In a southern Appalachian study, Beck and Olson (1968) combined data for five species of oaks (*Q. alba* *Q. coccinea*, *Q. prinus*, *Q. rubra*, *Q. velutina*) and found that only 24.6 percent of the acorns were sound and mature (Downs and McQuilken 1944).

Seed quality has also been reported for hickory species. In a 3-year study of *Carya glabra*, viable nuts were 11.6 percent of the total yield (Sork 1983). In southern Ohio, a 6-year study showed that *C. glabra* had 32.3 percent sound nuts, *C. ovata* had 47.5 percent, and *C. tomentosa* had 39.4 percent (Nixon et al. 1971).

Sound beechnuts (*Fagus grandifolia*) were generally represented as a small portion of the total crop. In 7 out of 10 years, sound beechnuts made up 10 percent or less of the yield (Gysel 1971).

Seasonal Patterns of Seed Fall

Poorly developed seeds begin to fall before well-developed seeds (Sork 1983, Strickland 1972, Downs and McQuilken 1944). A study of hickories in southern Michigan found that the majority of infested and aborted nuts are on the ground by mid-August (Sork 1983). Strickland (1972), in a study of selected oak species at the Tellico Wildlife Management Area, Tennessee, found that most immature acorns fall in the first two weeks of August. Poorly developed acorns in southern Appalachia first begin to fall about a month before well-developed acorns (Downs and McQuilken 1944).

For well-developed acorns in southern Appalachia, the period of drop tends to lengthen with larger crops. Usually, species of the white oak group begin dropping acorns before species of the red oak group. Even within a site, the time interval between the beginning and end of acorn drop may be 10 days to 5 weeks. Depending on species, the size of the crop and the weather, well-developed acorn drop begins in early September (Strickland 1972, Beck and Olson 1968, Downs and McQuilken 1944).

Soft Mast Surveys

Compared to hard mast surveys, very little information about soft mast surveying techniques is available in the literature. Uhlig and Wilson's (1952) survey method is not specifically for soft mast. However, most of the species listed for the understory group index, such as hawthorne (Crataegus spp.), crabapple (Malus spp.), dogwood (Cornus spp.), grapes (Vitis spp.), and blackberries (Rubus spp.), produce soft fruits. The soft mast species were surveyed the same way as hard mast species; observers describe fruit as abundant, common, or scarce, and an index is calculated from that information.

In Gysel and Lemmien's (1964) 8-year study, soft mast was surveyed in two different ways. Fruits from trees such as black cherry (Prunus serotina), European mountain ash (Sorbus aucuparia), hawthorne (Crataegus spp.), crabapple (Malus spp.), and Russian olive (Elaeagnus angustifolia) were collected in seed traps. Fruit from shrubs such as Tartarian honeysuckle (Lonicera tatarica), Siberian pea shrub (Caranga arborescens), silky dogwood (Cornus amonum), Cornelian cherry (Cornus mas), multiflora rose (Rosa multiflora), indigobush amorpha (Amorpha fruticosa), and ninebark (Physocarpus opulifolius) were collected from .19 m^2 (2 square feet) crown area to a depth of 10-13 cm (4-5 inches) from five permanently marked plants of each species. Results of the study showed that quantities of hard mast fruit were collected five out of eight years, while soft mast fruits were available every year.

Wildlife Utilization

Mast crop may have a regulatory influence on wildlife reproductive success, survival, size of population, and body condition (Goodrum et al. 1971). The response of squirrels (Sciurus spp.) to a good mast crop included improved survival of summer-born young, a lower rate of emigration of both juvenile and subadult squirrels, an increased fecundity of breeding males, and a higher rate of survival of adult squirrels (Nixon et al. 1975). Acorns in particular are

high in fat and carbohydrates and contain important vitamins and minerals (Strickland 1972). Gysel (1957) found that site quality not only affected acorn productivity but also chemical composition. Acorns from good and medium soil quality sites had higher percentages of ash, calcium, crude fiber, and protein than acorns from poorer sites.

Mast requirements of several species have been expressed in mass per area. Nixon et al. (1975) estimated that at least 147.3 kg of sound mast seeds per ha were needed to sustain high squirrel densities. Goodrum et al. (1971) concluded 4.5 kg of sound air-dry acorns per ha were needed to supply the dietary requirements of white-tailed deer (Odocoileus virginianus), gray squirrels (Sciurus carolinensis), fox squirrels (S. niger), turkey (Meleagris gallopavo), and bob-white quail (Colinus virginianus) in Missouri for 180 days. Gysel (1971) calculated that 12 dominant beech trees per ha could supply the energy requirement for 65 squirrel days.

Strickland (1972) reported that approximately 30.4 kg of mast per ha would be required to sustain the observed populations of white-tailed deer, gray squirrels, turkey, wild hog (Sus scrofa), and domestic cows for 90 days. Domestic animals such as hogs, goats, and cattle are known to feed on acorns in southern forests and are competitors with wildlife for mast crop (Goodrum et al. 1971). European wild hogs and domestic cattle require almost as much mast as deer, squirrel, and turkey combined (Strickland 1972). The European wild hog depends on mast for a significant portion of its diet. In 1960 and 1961, an acorn shortage on the Tellico Wildlife Management Area, Tennessee, was probably caused by the elm spanworm (Ennomos subsignarius). The wild hog subsequently subsisted on an energy deficient diet which produced an anestrus condition in the sows (Henry and Conley 1972, Matschke 1964).

Henry and Conley (1972) speculated that in a poor mast crop year, competition between native and exotic species may be acute. However, in a computer simulation of dietary competition in GRSM, the results indicated that competition of the hog with native wildlife was not important in either mast failure or heavy mast years (Cherry and Dearden 1975). Instead, high sciurid densities were found to be detrimental to other mast consumers. The black bear (Ursus americanus) was harmed the least by sciuriud competition, and the white-tailed deer, the most. However, these results must be regarded as preliminary, since model validation and testing are not completed.

METHODS

Field Sampling. The GRSM Management Division has used a mast survey developed by the Tennessee Wildlife Resources Agency (Whitehead 1969, 1980; Bill Cook, personal comm.). Although sampling philosophy was not described in print, the scheme implicitly consisted of a stratified random sample. The aim of the stratification was to spread the sampling throughout the park. This was accomplished by using 28 trails, selected for their representativeness, and by spacing samples regularly on the trails (Appendix B, Table B-1). During annual surveys on subsets, of the 28 trails (chosen arbitrarily), data collectors were instructed to sample eight random mast trees, using trees that were at least 0.8 km (0.5 mi) apart along approximately 6.4 km (4 mi) of trail. The number of trails sampled each year varied from 18 to 20. Approximate sampling sections were determined on topographic maps prior to data collection. On arriving at the sampling station, the data collector was instructed to sample the first hard mast-bearing tree (of any species) encountered that was at least 30.5 cm (12 inches) diameter at breast height (dbh = 4.5 ft; 1.37 m). The crown of this tree had to be intact--uninjured by wind or lightning strike. The topographic position of the tree was then marked on a USGS topographic map. It was, of course, crucial that no bias be interjected during the selection of the tree for sampling: the observers were instructed not to select a tree based on any personal notion that the tree was the best mast tree in the area, the most representative, or the worst mast tree in the area. The implicit intention of sampling method was that the selection was random against the available choices. Having arrived at an approximate location, this objective was met by sampling the first available tree, regardless of mast condition. Individual differences in estimation of hiking distance and such factors as the side of the trail from which the tree was selected were probably adequate in randomizing the actual tree selected. However, we will recommend below that randomization be more explicitly used.

Mast surveyors sampled the tree using binoculars. The percent of the tree crown that bore seeds was estimated. This percent was based on the crown silhouette as seen from the ground. Since the higher parts of the crown bear the most fruit, a logical interpretation is that this percent refers to the percent of the crown surface bearing fruit, rather than full crown volume. Five limbs approximately 1 m (3 ft) long were then selected from the productive part of the tree canopy. As far as practical, these limbs were randomly

selected. On each limb, samplers recorded the number of twigs present, the number of twigs with fruits, and the total number of fruits (Appendix A, Table A-2). The number of twigs with fruits was later divided by the total number of twigs to derive the percent of twigs with fruits.

While this survey was performed annually from 1977 to 1982, only data from the years 1979 to 1982 were extant in GRSM. However, summarized data for GRSM from the years 1977 to 1979 were published in a TWRA report (Whitehead 1980). Since the original intent was to analyze all data with the Whitehead (1969) index, we computed annual species indices using this methodology. Raw data were entered into the IBM Personal Computer at Uplands Field Research Laboratory and then transferred to the University of Tennessee's IBM 370/3081 mainframe computer. The data for each year were arranged in matrices (Appendix A, Tables A-3 to A-6), using SAS release 79.6 by means of a program called MASTDAT (Appendix A, Table A-7). A SAS program named MAST.SAS (Appendix A, Table A-8) was written to analyze the mast data using Whitehead's (1969) methodology.

We should underscore several facts about the sampling. As was described in the literature review, the data collected in the current mast survey result in relative numbers only--that is, no absolute yield values such as "kg per ha" or number of seeds per ha can be calculated. Further, there is no independent annual estimate of seed crop soundness. The index derived is a qualitative scalar; the implicit intent on this scalar is to portray the condition of mast for the whole park. Finally, because the samplers are free to select any hard mast species at each sampling station but only one species per station, sample size for particular species groups is uncontrolled. We return to these points in the discussion below.

Observer Bias Study. The validity of the mast survey is dependent on quality control and reliability. This is particularly true in sampling schemes such as this, in which observers are asked to estimate percentages. In order to test a part of the reliability of the mast survey program at GRSM, a study of observer bias was initiated.

Three data collectors were instructed by personnel from the Resources Management Division on how to sample mast using the techniques that are followed in the annual parkwide survey. Five routes were randomly selected from the data sheets (Appendix A, Table A-9--routes 12, 16, 17, 23, 26) and were sampled from August 28 to September 2, 1983. Each sampling day the three mast surveyors sampled a route. The data were analyzed following the procedures described above.

RESULTS

Analysis of 1979-1982 Data. Between 1979 and 1982, 14 mast species were surveyed on 28 trails (Table 2 and Appendix A, Tables A-3 to A-6). In 1979 and 1980, 11 species were sampled, for a total sample size of 147 and 160 trees, respectively. (These totals do not include data that were rejected because of missing values.) In 1981 and 1982, 12 species were sampled, for total sample sizes of 145 and 160, respectively.

The problem of varying sample sizes for particular species can be seen in Table 2. For example, several hickories (*Carya* spp.), black walnut (*Juglans nigra*), post oak (*Quercus stellata*), and blackjack oak (*Q. marilandica*) are not consistently present in the sample. In 1982, only six hickory trees were sampled, whereas 16 trees were sampled in 1979. In 1980, 19 beech trees were sampled, but sample sizes for the other three years for this species were low (Table 2). The only consistently high sample sizes were for white oak (N = 22-30), chestnut oak (N = 25-35), red oak (N = 31-54), and black oak (N = 12-28).

For the four years of mast survey data, 51 percent of the average indices were less than 2.5 (poor mast crop), and 34 percent were 2.6-4.5 (fair mast crop)(Table 2). Only two of the 53 values surpassed 6.6 (the lower bound of good mast crops). The species group averages for the park in the four years ranged from 0 to 4.2, indicating a range of mast crops from poor to fair. The two worst mast years appear to have been 1980 and 1982. In 1982, for example, 80 percent of the values were in the poor range and 40 percent of the values were 0.0. According to these data, 1979 and 1981 were fair years. The individual species groups behaved somewhat independently. For example, 1980 was a much better year for the red oak group (Index = 3.9) than for the white oak group (Index = 0.5) (Table 2). The year 1981 was the best for hickory (Index = 3.8), beech (Index = 8.0, but note that only one tree was sampled) and the white oak group (Index = 3.8), whereas this was the second worst year for the red oak group (Index = 2.2).

Further statistical analyses of these data are, of course, possible. For example, mast differences could be examined by elevation, site factors, or tree diameter. Statistical tests (e.g., the t-test; see Whitehead 1980) could be used to examine the significance of year-to-year differences. We chose not to carry these analyses out at this time for several reasons. One reason is sample size. Since the overall sampling strategy was not designed

Table 2. Parkwide mast indices for 1979, 1980, 1981, 1982.

	1979 (N=147)	1980 (N=160)	1981 (N=145)	1982 (N=160)
(Hickories)				
Unidentified Carya	4.8 (N=5)	0.0 (N=2)	2.5 (N=2)	0.0 (N=2)
Carya cordiformis	-	3.0 (N=1)	4.0 (N=1)	-
Carya glabra	_	-	5.0 (N=1)	0.0 (N=1)
Carya ovata	1.5	0.0 (N=2)	5.3 (N=3)	1.0 (N=2)
Carya tomentosa	4.4 (N=9)	1.6 (N=5)	3.0 (N=4)	1.0 (N=1)
Group average	4.2 (N=16)	1.1 (N=10)	3.8 (N=11)	0.5 (N=6)
(Beech)				
Fagus grandifolia	1.6 (N=7)	1.6 (N=19)	8.0 (N=1)	0.0 (N=2)
(Walnuts)				
Unidentified Juglans	-	-	-	0.0 (N=1)
Juglans nigra	5.5 (N=4)	0.0 (N=1)	-	0.0 (N=3)
(White Oaks)				
Quercus alba	3.0 (N=23)	0.8 (N=22)	3.4 (N=30)	0.5 (N=29)
Quercus prinus	3.3 (N=35)	0.0 (N=30)	4.3 (N=26)	0.2 (N=25)
Quercus stellata	5.0 (N=1)	-	-	0.0 (N=1)
Group average	3.2 (N=59)	0.4 (N=52)	3.8 (N=56)	0.3 (N=55)
(Red Oaks)				
Unidentified Red Quercus			1.0 (N=7)	2.9 (N=8)
Quercus coccinea	0.7 (N=3)	6.7 (N=4)	4.1 (N=7)	0.7 (N=9)
Quercus falcata	1.7 (N=11)	2.8 (N=5)	4.0 (N=3)	3.8 (N=8)
Quercus marilandica	-	-	5.0 (N=1)	-
Quercus rubra	3.2 (N=35)	4.1 (N=46)	1.6 (N=31)	1.2 (N=54)
Quercus velutina	3.5 (N=12)	3.4 (N=23)	2.3 (N=28)	2.9 (N=14)
Group average	2.9 (N=61)	3.9 (N=78)	2.2 (N=77)	1.7 (N=93)
All species average	3.1	2.3	3.0	1.2
Percent of Indices				
0-2.5	33	58	29	80
2.6-4.5	33	33	43	20
4.6+	33	9	28	0

The following relationship was established between these numerical ratings and mast crop quality (Whitehead 1969).

Numerical Rating	Crop Quality
0 - 2.5	Poor
2.6 - 4.5	Fair
4.6 - 6.5	Medium
6.6 - 8.5	Good
8.6 -10.0	Excellent

around environmental or biological parameters, actual sample sizes for subsets of the data are small and uncontrolled. The current survey strategy is best considered on the all-park, all-species level; that is, as a sample of average mast crop. Our primary concern in further statistical analysis of the 1979 - 1982 data was the less-than-optimum timing of the survey. We suspect that the most important factor influencing variation in these data was the time period of the sample relative to the onset of natural mast drop rather than such factors as species and site differences in actual mast crop size. The late timing of the survey may explain the low mast indices that were observed in the four years of data we analyzed.

In 1979, 18 trails were sampled in a 26-day period from September 2 to September 27. In 1980, 20 trails were sampled in a 29-day interval from August 14 through September 11. In 1981, 18 trails were sampled in a 21-day interval from August 31 to September 20. In 1982, 20 routes were sampled in a 34-day period from August 14 to September 16. In order for data to be comparable from year to year, estimates must be completed in a short period of time and before late August in the southern Appalachians (Strickland 1972, Sharp 1958). Beck and Olson (1968) showed that the fall of sound acorns occurred throughout September in the South. Sharp (1958) observed that squirrels begin cutting acorns and hickory nuts by mid-August. In years of medium to light yields, the crop may be significantly reduced by consumption or caching by the first of September. Because the park data were collected late in the year, both significant mast drop and wildlife utilization is probable. Field data sheets have frequent comments from samplers stating the mast drop was underway.

GRSM has selected tree counts of mast crops as the best alternative for an efficient all-park survey. Timing of the survey is a significant factor in such surveys; we return to this point in the discussion.

Observer Bias Study. The mast index computed for each species is listed by observer in Table 3 (see Appendix A, Table A-9, for the raw data). A one-way analysis of variance (Sokal and Rohlf 1981) was performed on these data, using a Type II model, to test the differences between the three observers for each of four species or species groups (hickories, beech, red oaks, white oaks). Mast indices did not vary significantly among the three samplers (the probability of F statistics greater than those observed ranged from .054 to .81). All three observers classified the hickory, white oak group, and red

Table 3. Mast indices for observer bias study

	1	2	3
(Hickories)	(N=28)	(N=40)	(N=40)
Carya cordiformis	2.0 (N=1)	-	-
Carya tomentosa	-	2.0 (N=1)	0.5 (N=4)
(Beech)			
Fagus grandifolia	1.0 (N=2)	3.4 (N=7)	2.1 (N=9)
(White Oaks)			
Quercus alba	0.4 (N=5)	0.0 (N=5)	0.3 (N=3)
Quercus prinus	0.3 (N=4)	0.6 (N=9)	0.0 (N=10)
(Red Oaks)			
Quercus coccinea	-	0.0 (N=3)	0.0 (N=1)
Quercus rubra	0.0 (N=14)	0.9 (N=14)	0.9 (N=13)
Quercus velutina	0.0 (N=2)	-	-

The following relationship was established between these numerical ratings and mast crop quality (Whitehead 1969).

Numerical Rating	Crop Quality
0 - 2.5	Poor
2.6 - 4.5	Fair
4.6 - 6.5	Medium
6.6 - 8.5	Good
8.6 -10.0	Excellent

oak group crops as poor. Two observers rated the beech crop as poor, and a third rated it as fair. These qualitative differences (only one discrepancy in 12 classifications) are relatively minor, given the nature of the data set.

Thus the observer bias study did not show significant problems with inherent sampling differences among observers. However, we timed this study with the overall GRSM mast index survey program for 1983, at the beginning of our research project. When mast crops are low (as our results suggest), observer differences may be less than when they are moderate or high because of frequent "zeroes" in the data. Because mast timing influences low mast indices, the observer bias data should be repeated during a better timed survey.

1977-1979 GRSM Data in Whitehead (1980). Data from GRSM for the years 1977, 1978, and 1979 are printed in Tables 9 to 18 of Whitehead (1980). The data are summarized for the whole park and for all species and also for species groups in five drainages and several elevation classes. As might be expected, sample size is low in some of these data subsets.

Of these data, only the 1979 data were collected by National Park Service personnel (M. Pelton, personal communication). Mean mast index and total sample size for the other two years were reported as 3.3 and 76 (1977) and 1.1 and 106 (1978). Since we did acquire the raw data sheets for 1979, we were able to compare our parkwide mast index with Whitehead's (1980), which was supposedly based on the same algorithm. Whitehead reported a value of 3.9 (N=147), whereas our calculation, apparently based on the same data, was 3.1 (N=147). Since Whitehead (1980) did not document his computational methods and may have made different choices than we did with regard to the editing of the data, we cannot explain this difference at this time.

DISCUSSION

Tipton and Otto (1979) offered evidence that tree counts were the most efficient method for surveying GRSM mast crop size. We suggest some improvements in the way data are currently collected. For example, several minor alterations would render the existing field methods more reliable. Emphasis in tree identification should be placed on fruit twigs and bark characteristics as well as leaf identification. During training sessions, visual aids, such as slides and examples of tree bark, should be presented. Because of problems in species identification and because of uncontrolled sample sizes for individual species, we conclude that mast indices are most

useful at the genus (Carya, Juglans) or group (red oak group, white oak group) level rather than at the level of individual species. If individual species are the level of focus, the sample should be stratified by species, as in other mast survey regimes (e.g., Sharp 1958).

The GRSM mast survey uses a data sheet provided by TWRA (Appendix A, Table A-2). This data sheet can be improved for easier and more complete data entry. We have designed a modified form (Appendix B, Table B-5), which includes space for tree diameter, elevation, and route number (see Appendix B, Table B-3 for these route numbers). Route numbers should be copied on the data sheet before sampling. Maps with sampling stations marked should be provided prior to the survey.

We have also included on the revised data sheet a series of boxes for recording percent of the tree crown with seeds to the nearest 20 percent. The appropriate box should be checked. Because there is a differential bias in percentage estimates from one observer to another (Barbour et al. 1980), present cover estimates (i.e., to the nearest percent) demand an unrealistic level of precision.

The last portion of the new survey form is a list of reminders. The usefulness of the past data is compromised by missing values (for example, percent of crown with seeds, species names). We have also included an outline of the sampling scheme in a handout to be used in the field (see Appendix B, Table B-4).

As a more substantive change in present field methods, we suggest that an upper diameter limit be used in the selection of the trees for sampling, as well as the current lower diameter limit. The optimum tree diameter range to ensure the sampling of average canopy trees is 30-75 cm (12-30 inches) dbh (Downs 1944). Juveniles and older trees have consistently low seed crops independent of the overall quality of the mast year.

The most important problem with past data is that seed fall influenced the number of nuts still on the trees at the time of the survey. Other literature reports from the southern Appalachians suggest that the optimum timing of a tree-based mast survey is for sampling during the month of August. Evidence suggests that the survey should be completed by mid- to late August. All four years of data that we analyzed included September sampling dates. Notes on the field data sheets suggested that seed fall had begun at the time of sampling. The lateness of the 1983 sampling influenced the observer study as well; this study should be repeated, combined with a further analysis of

optimum survey timing. Visibility of mast bearing twigs is more difficult in mid-August than late September, but heavy leaf fall has not occurred, even at the later date. Further, mid-August surveys have been carried out successfully elsewhere. The most important reason for timing is that crown count surveys must be carried out before mast drop.

In order for mast data to provide useful information to wildlife biologists, the data should be analyzzed the same year it is collected. This would also increase the likelihood that missing data could be recovered. We include a chart showing a suggested schedule for sampling and data analysis (Appendix B, Table B-1). Data set curation is also required to ensure original data are not lost. Appendix B is intended to be extracted for use in the hard mast survey. Tables B-1 and and B-2 are the schedule and guidelines for the mast survey project leader. The survey routes are described and coded in Table B-3. Tables B-4 and B-5 include a sampling checklist and revised data sheet. Table B-6 gives the TWRA and GRSM codes for the different mast species to be used when entering the data into a computer.

Another discussion point is mast index calculation. The park survey program intended to use the index proposed by Whitehead (1969, 1980). This index is also used by TWRA. There is no biological rationale for adding together the three numbers on which it is based (percent of crown producing fruits, and the number of fruits per twig). It would seem much more logical to multiply these numbers. Thus, if 50 percent of an oak crown bears acorns and 50 percent of the twigs within the productive part of the crown bears acorns, then 25 percent of the crown's twigs bear acorns by multiplication. The addition of these numbers to one another is, by contrast, arbitrary.

There is a further problem in the addition of the number of fruits per twig to the two numbers mentioned above. As Sharp (1958) noted, the maximum number of fruits per twig, even in a bumper year, varies with species. For example, oaks have higher numbers of fruits per twig than hickories or walnuts, and red oaks have higher numbers than white oaks. Thus, species with characteristically low numbers of fruits per twig will always have a lower range of index numbers than species with characteristically high numbers. This problem is further complicated by the frequent relationship between average fruit number and average fruit weight: species with low

average fruit numbers per twig often have heavier fruits (e.g., acorn versus walnuts). In an absolute and caloric sense, this would compensate for lower absolute numbers.

Sharp's (1958) solution to this problem was rating each species or species group against its own maximum possible production in terms of fruits per twig. Thus the fruit count would be converted to a percentage value (i.e., the percentage of the maximum possible fruit number). Sharp (1958) included a scheme for the white and red oak groups, but equivalent numbers would have to be developed for other hard mast genera. These data would, however, be relatively easy to gather.

Combining the Whitehead sampling scheme (the method now being used in GRSM), multiplication of base numbers (see rationale above), and normalization for differences in fruit crop size among species (Sharp 1958), we propose the following formula:

$$N_i = \frac{(C_i * T_i * F_i)}{10^4}$$

where:

N_i is the percent of maximum possible mast crop size for the ith sample tree,

C_i is the percent of the crown with fruit for the ith sample tree,

T_i is the percent of twigs within the productive part of the crown which bear fruit for the ith sample tree, thus (see below)

F_i is the percent of the maximum number of fruits per twig for the ith sample sample tree (see below),

and 10^4 is used to scale the index between 0 and 100.

The value "N_i" can then be average within species or species groups, as follows:

$$\bar{N}_s = \sum_{i=1} N_i / n_s$$

where:

$\bar{N}_s$ is the mean index for species s,

N_i is the index for the ith sample tree

and n_s is the number of trees sampled in species s.

T_i is calculated from the fire sample limbs on each sample tree (see Appendix B) as follows:

$$T_i = \sum_{i=1}^{5} t_i / 5$$

where

t_i is the percent of twigs with fruit on the ith sample limb.

F_i, the percent of maximum fruit crop per twig for the ith sample tree, is calculated from the fi sample twigs on the ith tree as follows:

$$F_i = [\sum_{h=1}^{5} f_h/F_{max}] * 100$$

where

f_h is the number of fruits on the hth twig of the sample limb on the ith sample tree (this number sample tree (this number is already recorded in the current sampling scheme--see Appendix B),

and

F_{max} is the maximum possible number of fruits per twig.

F_{max} must be derived separately for each mast bearing species. This maximum would be established through intensive species-specific analysis during good mast years. If F_h rarely reaches its maximum value (F_{max}), the maximum can be scaled to a more reasonable limit (e.g., .9 F_{max}). A statistical rationale and computation for such a scaled upper limit is given in Cochran (1977). The same rationale can be used to further refine the values C_i and T_i. If it is found that these values rarely reach 100, they could also be scaled within the average maximum reached in good mast years.

Finally, an overall mast index can be computed for each species group or for all hard mast species, using the following formula:

$$I_k = \sum_{s=1} \frac{n_s \bar{N}_s}{(\Sigma n_s)*10}$$

where

I_k is the mast index for the group of interest,

n_s is the sample size for the sth species

and

$\bar{N}_s$ is the mean percent of maximum mast crop size based on the trees sampled for the sth species.

We have divided by 10 in this equation to give a scalar ranging from 1 to 10.

One virtue of this amended procedure is that it uses the same sampling sscheme as currently employed. In addition, the data can still be shared with TWRA, and the Whitehead index numbers can be computed.

An alternative of the above modification is to use the Sharp (1958) sampling regime. This method would require a change in data collection procedure. Sharp's method is based on representative tree counts and it has been used in a number of published reports. (There is, however, no clearly dominant mast survey technique now found in the published literature).

Seed condition is not evaluated by the tree count method. Whitehead (1969, 1980) suggested that an average of 52 percent of all mast fruits were sound. However, a review of the literature indicates that seed condition varies by species by year. Tipton and Otto (1979) pointed out that seed traps could be used for assessment of mast quality in GRSM. Seed quality should not be assessed by samples brought in by surveyors; aborted and unsound seeds fall before sound seeds, and it would be difficult to ensure a random sample. Thus the optimum mast survey program would include an annual assessment of mast quality, and the mast samples could also be used to derive nutritive value. Seed traps would be used on a subset of the areas and would have to be easily accessible for biweekly sampling from August 15 to October 1. If data were available on mast quality, the percent of sound acorns should be multiplied times the average number of fruits per twig used in the calculations described to correct for aborted or damaged seeds.

A final issue in the current GRSM mast survey program concerns the feasibility of a soft mast survey. Whereas such a survey may be desirable in the long run, we do not recommend a soft mast survey at this time. Soft mast fruits are only moderate in food value compared to hard mast (for example, they are less rich in protein and have lower caloric values per volume or weight; Wainio and Forbes 1941). Further, there is some evidence that soft mast production is more consistent from year to year than hard mast and therefore less critical in its influence on wild hog population. However, wild grape crops can be important in wild hog diets (Scott and Pelton 1975) and bear use habitat (M. Pelton, personal communication); and past park disturbances (principally logging and chestnut blight) have resulted in large grape thickets throughout the park. We concluded, however, that a soft mast survey is less important than optimizing the hard mast survey.

Although we concur and tree counts are the most efficient way to survey GRSM mast crop (especially since current use of the date is qualitative, estimates

of absolute mast production (mass per unit area of caloric value per unit area) would be more ecologically meaningful than the present dimensionless scalar. As already noted, the survey itself includes no estimate of acorn or nut quality and hence no correction for year to year changes in percent soundness. Below we address these problems. We should, however, note that the solutions increase the expense and time involved in the mast survey program.

An optimum mast survey would correct both of these deficiencies. Seed traps should be used, not for the parkwide index but rather to develop data on seed soundness for randomly chosen study trees. The seeds collected could be dried, weighed, and analyzed for caloric content. The absolute production of individual trees used in the seed trap study could then be used to calibrate mast index scalars developed for the same trees in terms of estimates of total absolute production per tree. Such a calibration could then be used to interpret mast index data from the parkwide tree count survey. Whitehead (1969) attempted such a calibration for the Tellico Wildlife Management Area, but insufficient data have been published from this survey to warrant direct use of his data.

The seed trap survey should be carried out biweekly from August 15 to October 1. Such data collection would be labor intensive. Further, the design of the seed traps, the number of seed traps at each sampling point, and the number of sampling points would initially be the subject of feasibility studies rather than direct application of existing knowledge. Our current conclusion is that the top priority for the GRSM hard mast survey is the optimization of the current survey regime itself, and the timely reporting and use of the survey results rather than an immediate increase in the scope of the project.

Ground count surveys are attractive for several reasons and should be the focus of a future feasibility study. Ground counts give the most direct measurement of mast available to the wild hog. The amount of mast on the ground from November to February may be the single most important and most directly measurable property of mast crop with regard to wild hogs. Although ground counts do not correct for aboreal feeders, it can be argued that mast availability after aboreal feeding is more important than total mast crop size. Ground counts do, however, underestimate mast availability to hogs with regard to rodent caches--hogs are known to utilize these food stores.

The disadvantages of ground count surveys are the labor-intensive nature of the sampling and the long season of mast crop availability. Surveys should be carried out biweekly and, if used as the sole source of mast crop data, would

require a large number of random survey points. Further, the data are less useful in management planning (e.g., allocation of manpower to hunting versus trapping) because the data are developed during the same season (winter) in which management actions based on the mast survey must take place. The crown surveys are completed well in advance of management actions. Finally, because of differential use of wildlife, ground counts underestimate mast quality.

The final kind of data that is required to convert the mast survey data to absolute production (e.g., mass per ha) concerns the extrapolation from individual trees to an area basis. Two general strategies could be used in this regard. First, when an all-park vegetation map is available, the field survey can be stratified by community type, and data can then be extrapolated to an area basis by means of the computerized vegetation map. The second strategy is essentially that described by Whitehead (1969). Bitterlich prism talleys are used to sample the basal area per unit area for hard mast species. These Bitterlich prism talleys should be carried out at random sampling points along the survey routes. The prism talleys should not be carried out after the surveyor selects the hard mast tree for the crown count because the talley would then not be representative of the survey route as a whole. Even if the Bitterlich sampling points were random, this strategy requires the assumption that the survey route corridors (i.e., trailsides) are representative of the general habitat area for hard mast species in the immediate vicinity of the routes themselves (e.g., the watershed in which the survey routes are found). Since trails may indeed be a biased sample of topography and hence community types, this assumption may very well be invalid.

We prioritize these choices for the mast survey in the following manner. First, the revised crown count survey should be implemented as soon as possible, with an observer bias survey carried out on five randomly chosen trails. The data should be reported and used in management decisions for hog control during the following winter. Pending the successful institution of this program, seed trap and ground count surveys could then be initiated. The availability of a parkwide vegetation map should make the extrapolation of this data feasible at that time.

CONCLUSIONS

1. The most appropriate method for a parkwide survey of relative mast crop size is that already in use--a stratified random smple based on mast tree counts. The sample is stratified by the selection of 20 geographically distributed sample routes and the use of uniform spacing between sampling trees. If less than the total number of trails is sampled in a good year, as has been the rule, the actual trails sampled should be random. The actual trees sampled should be between 30 and 75 cm (12 and 30 inches) in diameter but should be chosen randomly at sampling locations. If there is a requirement for valid data at the species level, the sample should be stratified by species to ensure a minimum sample size is obtained in any given year. Sample size for species currently is uncontrolled.

2. The survey should be carried out during mid-August, with data collection completed by September 1.

3. An observer bias study should be incorporated into the survey.

4. Data should be analyzed in the year of sampling.

5. Indices should be calculated for species groups (hickories, beech, walnuts, red oak group, white oak group) and for all species, using this index. There should be a timely report of the data summary.

6. Ideally, mast quality should be assessed by means of seed traps sampled from early August to late September. Seed soundness varies among years and among species. If data on mast quality are lacking, mast quantity is overestimated by at least 5 to 50 percent (see Literature Review).

7. While soft mast may be important in wild hog diet and bear habitat use, a soft mast survey is not recommended at this time because soft mast is probably less predictably related to winter survival of the wild hog than is hard mast.

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APPENDIX A

Table A-1. Calculation sheet for dot talley method.

OAK MAST SURVEY

DATE______________ AREA____________ LOC.__________ ELEV.________

CRITERION	Percentage or Number of Acorns				
	0-5%	6-33%	34-66%	67-100%	
	0	1-2	3-4	5-6	7+
Percentage of Crown Producing Acorns					
Percentage of Twigs Bearing Acorns					
Average Number of Acorns per Twig					

Table A-2. Sample survey sheet used by TWRA and GRSM

HARD MAST SURVEY

Date__________ Area_______ County________________ Route #_____________ Elevation________

Species	Limb No.	No. Twigs	No. Twigs w/Acorns	Total No. Acorns
	1			
Code	2			
	3			
% of Crown w/Acorns	4			
	5			
Total	5			

Species	Limb No.	No. Twigs	No. Twigs w/Acorns	Total No. Acorns
	1			
Code	2			
	3			
% of Crown w/Acorns	4			
	5			
Total	5			

Species	Limb No.	No. Twigs	No. Twigs w/Acorns	Total No. Acorns
	1			
Code	2			
	3			
% of Crown w/Acorns	4			
	5			
Total	5			

Species	Limb No.	No. Twigs	No. Twigs w/Acorns	Total No. Acorns
	1			
Code	2			
	3			
% of Crown w/Acorns	4			
	5			
Total	5			

Species	Limb No.	No. Twigs	No. Twigs w/Acorns	Total No. Acorns
	1			
Code	2			
	3			
% of Crown w/Acorns	4			
	5			
Total	5			

Species	Limb No.	No. Twigs	No. Twigs w/Acorns	Total No. Acorns
	1			
Code	2			
	3			
% of Crown w/Acorns	4			
	5			
Total	5			

Species	Limb No.	No. Twigs	No. Twigs w/Acorns	Total No. Acorns
	1			
Code	2			
	3			
% of Crown w/Acorns	4			
	5			
Total	5			

Species	Limb No.	No. Twigs	No. Twigs w/Acorns	Total No. Acorns
	1			
Code	2			
	3			
% of Crown w/Acorns	4			
	[illegible]			
Total	5			

COMMENTS:____

____

Name:____

Tables A-3 to A-6 and A-10. Hard mast survey for 1979 to 1982.

DATE:	refers to the month, day, and year the tree was sampled
TRAIL:	refers to the trail code
SPECIES:	refers to the tree species code given in Table 1
DBH:	refers to the tree's diameter at breast height in cm
ELEV:	refers to the elevation (in feet) of the sampling site
CANOPY:	refers to the percent of productive canopy
TWIG:	refers to the total number of twigs counted on 5 limbs of a sampled tree
TWIGACRN:	refers to the total number of twigs with seeds counted on 5 limbs of a sampled tree
ACORN:	refers to the total number of seeds counted on 5 limbs of a sampled tree

Table A-3. 1979 GRSM mast survey data

1979 MAST SURVEY

DATE	TRAIL	SPECIES	DBH	ELEV	CANOPY	TWIG	TWIGACRN	ACORN
90279	3	QRCALB	13	1850	35	18	10	17
90279	3	QRCALB	18	1850	5	18	1	2
90279	3	QRCPRN	15	1850	40	18	11	15
90279	3	QRCPRN	13	1850	.	25	15	35
90279	3	QRCFLC	23	1850	60	21	10	19
90279	3	QRCRBR	8	1850	10	21	4	6
90279	3	QRCPRN	8	1850	40	23	10	14
90279	3	QRCFLC	13	1850	.	28	8	12
91279	4	QRCFLC	19	1800	0	38	1	1
91279	4	JGLNGR	28	1800	60	34	18	26
91279	4	QRCALB	28	1800	100	34	15	169
91279	4	QRCRBR	25	1800	0	36	0	0
91279	4	CRYTMN	10	1800	70	35	12	19
91279	4	QRCRBR	7	1800	0	30	0	0
91279	4	CRYOVT	15	1800	0	20	0	0
91279	4	QRCALB	24	1800	90	30	18	34
91779	23	QRCRBR	30	.	90	21	12	29
91779	23	QRCRBR	10	.	80	19	9	12
91779	23	QRCVLT	34	.	10	23	3	3
91779	23	QRCVLT	34	.	10	23	3	3
91779	23	QRCALB	22	.	20	22	8	7
91779	23	CRYTMN	21	.	100	26	22	48
91779	23	QRCVLT	35	.	100	25	15	58
91779	23	QRCALB	18	.	10	19	5	6
91779	20	QRCRBR	38	.	20	23	3	3
91779	20	QRCRBR	34	.	60	23	16	29
91779	20	QRCPRN	34	.	60	21	9	13
91779	20	QRCALB	27	.	10	23	4	5
91779	20	QRCRBR	27	.	10	27	1	1
91779	20	QRCRBR	17	.	90	22	10	23
91779	20	QRCALB	24	.	80	16	11	21
91779	20	QRCRBR	26	.	0	24	0	0
92079	2	QRCFLC	10	.	0	23	1	1
92079	2	QRCFLC	35	.	0	32	0	0
92079	2	QRCPRN	35	.	0	42	0	0
92079	2	QRCPRN	35	.	10	34	3	3
92079	2	QRCPRN	35	.	0	37	1	2
92079	2	QRCFLC	30	.	.	43	0	0
92079	2	QRCFLC	35	.	0	49	0	0
92079	2	QRCFLC	24	.	0	42	0	0
91679	14	QRCPRN	12	.	50	20	4	4
91679	14	QRCPRN	16	.	80	13	4	4
91679	14	QRCPRN	24	.	90	28	18	29
91679	14	QRCPRN	40	.	100	26	13	24
91679	14	QRCPRN	20	.	90	31	14	27
91679	14	QRCPRN	22	.	100	22	13	19
91679	14	QRCPRN	26	.	100	26	14	18
91679	14	QRCPRN	24	.	90	20	9	17
91579	1	QRCPRN	18	1750	100	49	27	71
91579	1	QRCALB	11	1750	60	29	14	34
91579	1	QRCRBR	17	1750	0	38	0	0

Table A-3 (cont.)

1979 MAST SURVEY

DATE	TRAIL	SPECIES	DBH	ELEV	CANOPY	TWIG	TWIGACRN	ACORN
91579	1	CRYTMN	.	1750	100	27	21	58
91579	1	QRCRBR	21	1750	0	23	0	0
91579	1	QRCALB	22	1750	80	39	23	39
91579	1	QRCRBR	24	1750	40	25	7	14
91579	1	QRCRBR	26	1750	40	27	10	32
91879	29	QRCPRN	12	5550	0	23	1	1
91879	29	FGSGRN	9	5550	10	31	3	6
91879	29	FGSGRN	9	5550	0	20	0	0
91879	29	ASCOCT	12	5550	0	34	0	0
91879	29	ASCOCT	12	5550	0	34	1	1
91879	29	FGSGRN	12	5550	0	32	0	0
91879	29	ASCOCT	16	5550	0	39	0	0
91879	29	FGSGRN	10	5550	0	25	0	0
91979	5	QRCPRN	18	.	0	44	0	0
91979	5	QRCPRN	10	.	100	30	15	31
91979	5	QRCPRN	17	.	0	39	0	0
91979	5	QRCPRN	12	.	100	29	21	42
91979	5	QRCFLC	28	.	40	40	7	16
91979	5	ASCOCT	10	.	0	34	0	0
91979	5	ASCOCT	16	.	0	37	0	0
91979	5	FGSGRN	13	.	0	42	0	0
90779	12	QRCPRN	25	.	30	26	9	12
90779	12	QRCPRN	22	.	90	25	23	41
90779	12	QRCFLC	10	.	30	28	8	9
90779	12	QRCRBR	10	.	10	21	5	6
90779	12	QRCVLT	17	.	80	22	17	21
90779	12	QRCVLT	21	.	40	22	11	18
90779	12	QRCRBR	12	.	60	23	10	11
90779	12	QRCVLT	14	.	90	17	11	31
91079	6	QRCPRN	9	2650	60	28	9	14
91079	6	QRCVLT	11	2650	0	25	0	0
91079	6	QRCVLT	14	2650	0	22	2	2
91079	6	QRCPRN	21	2650	70	24	11	23
91079	6	QRCALB	9	2650	40	18	8	9
91079	6	QRCVLT	21	2650	70	23	13	31
91079	6	QRCRBR	17	2650	0	22	0	0
91079	6	QRCPRN	25	2650	90	23	13	20
90879	17	CRYOVT	19	.	60	30	7	7
90879	17	QRCRBR	26	.	30	33	2	2
90879	17	QRCPRN	20	.	40	33	6	7
90879	17	QRCPRN	19	.	100	30	11	15
90879	17	QRCPRN	30	.	60	26	8	11
90879	17	QRCPRN	13	.	60	23	3	3
90879	17	QRCRBR	33	.	100	22	16	75
90879	17	QRCRBR	23	.	80	20	16	69
91479	27	CRYTMN	13	.	.	17	9	20
91479	27	JGLNGR	26	2200	100	17	13	25
91479	27	CRY	13	2200	70	17	6	11
91479	27	QRCRBR	15	2200	0	22	0	0
91479	27	QRCPRN	12	2200	0	31	0	0
91479	27	CRYTMN	16	2200	70	21	8	13

Table A-3 (cont.)

1979 MAST SURVEY

DATE	TRAIL	SPECIES	DBH	ELEV	CANOPY	TWIG	TWIGACRN	ACORN
91479	27	CRYTMN	16	2040	100	20	12	14
91479	27	QRCALB	18	2040	0	21	0	0
91479	26	QRCVLT	18	.	20	19	2	2
91479	26	FGSGRN	13	5338	100	52	34	57
91479	26	QRCRBR	18	4700	10	30	4	6
91479	26	QRCRBR	27	.	60	25	12	25
91479	26	QRCRBR	23	.	90	27	17	25
91479	26	QRCRBR	20	5000	100	32	23	89
91479	26	QRCALB	12	3145	0	23	0	0
91479	26	JGLNGR	15	3000	80	24	8	17
92079	31	QRCVLT	24	.	100	28	22	52
92079	31	QRCRBR	24	.	100	28	22	52
92079	31	QRCALB	17	.	60	10	6	5
92079	31	QRCALB	31	.	0	22	0	0
92079	31	QRCPRN	15	.	0	16	0	0
92079	31	QRCRBR	15	.	100	19	18	61
92079	31	CRY	15	.	100	20	12	20
92079	31	CRY	17	.	60	10	6	5
92479	32	QRCCCC	16	1750	30	17	4	4
92479	32	CRY	10	1750	50	20	7	8
92479	32	JGLNGR	20	1750	100	23	17	30
92479	32	QRCALB	14	1750	90	24	6	7
92479	32	QRCPRN	20	1750	30	21	4	5
92479	32	CRY	12	1750	80	32	20	30
92479	32	QRCFLC	30	1750	80	32	21	49
92479	32	QRCRBR	.	1750	30	33	5	7
91779	32	QRCALB	24	2300	20	72	2	3
91779	32	QRCALB	11	2300	20	67	1	1
91779	32	QRCCCC	11	2300	0	85	0	0
91779	32	QRCPRN	22	2300	20	75	2	2
91779	32	QRCSTL	11	2300	90	34	14	28
91779	32	QRCALB	13	2300	0	56	0	0
91779	32	CRYTMN	14	2300	80	43	7	9
91779	32	QRCCCC	16	2300	0	53	2	2
91679	34	QRCRBR	9	.	0	20	0	0
91679	34	QRCALB	22	.	70	23	13	26
91679	34	QRCRBR	.	.	90	22	7	9
91679	34	FGSGRN	21	.	50	46	9	13
91679	34	QRCALB	10	.	0	23	0	0
91679	34	QRCRBR	22	.	80	27	20	47
91679	34	QRCALB	25	.	40	22	6	11
91679	34	QRCALB	9	.	50	25	10	19
91879	28	CRYTMN	15	.	20	10	3	3
91879	28	CRYTMN	11	.	0	10	0	0
91879	28	QRCRBR	23	.	0	21	0	0
92879	28	QRCVLT	32	.	0	21	0	0
91879	28	QRCPRN	15	.	0	18	0	0
91879	28	QRCRBR	17	.	60	15	10	22
91879	28	QRCRBR	20	.	0	19	0	0
91879	28	QRCRBR	21	.	0	23	0	0

Table A-4. 1980 GRSM mast survey data

1980 MAST SURVEY

DATE	TRAIL	SPECIES	DBH	ELV	CANOPY	TWIG	TWIGACRN	ACORN
81480	3	QRCALB	13	1850	0	38	0	0
81480	3	QRCALB	14	1850	0	39	0	0
81480	3	QRCPRN	16	1850	0	31	0	0
81480	3	QRCPRN	13	1850	0	43	0	0
81480	3	QRCRBR	23	1850	100	28	28	87
81480	3	QRCRBR	14	1850	40	30	11	28
81480	3	QRCPRN	19	1850	0	34	0	0
81480	3	QRCRBR	13	1850	0	41	0	0
81480	4	QRCFLC	19	1800	20	40	9	25
81480	4	JGLNGR	28	1800	0	33	1	1
81480	4	QRCALB	29	1800	0	27	0	0
81480	4	QRCRBR	25	1800	40	35	19	47
81480	4	CRYTMN	10	1800	0	29	0	0
81480	4	QRCFLC	15	1800	30	39	21	36
81480	4	CRYOVT	12	1800	0	34	0	0
81480	4	QRCALB	24	1800	0	39	0	0
81580	6	QRCALB	11	.	0	29	0	0
81580	6	QRCRBR	11	.	70	33	20	59
81580	6	QRCALB	22	.	0	38	0	0
81580	6	QRCRBR	22	.	100	31	29	270
81580	6	QRCPRN	24	.	0	35	0	0
81580	6	QRCRBR	16	.	100	30	22	165
81580	6	CRY	21	.	0	27	0	0
81580	6	CRY	16	.	0	36	0	0
81980	32	QRCALB	12	2200	10	39	3	4
81980	32	QRCVLT	22	2200	100	40	21	47
81980	32	QRCVLT	16	2200	70	28	9	14
81980	32	CRYCRD	8	2200	50	29	6	7
81980	32	QRCCCC	14	2200	90	30	17	38
81980	32	CRYTMN	10	2200	40	30	3	3
81980	32	QRCPRN	13	2200	0	25	0	0
81980	32	QRCCCC	19	2200	90	24	13	43
82180	1	QRCPRN	18	.	0	39	0	0
82180	1	QRCALB	11	.	0	28	0	0
82180	1	QRCRBR	17	.	85	26	23	107
82180	1	CRYTMN	24	.	0	25	0	0
82180	1	QRCRBR	21	.	0	26	0	0
82180	1	QRCALB	22	.	0	37	0	0
82180	1	QRCRBR	24	.	20	27	9	19
82180	1	QRCRBR	26	.	10	29	10	20
82180	27	QRCALB	15	2000	40	37	8	15
82180	27	QRCRBR	32	2000	80	30	22	63
82180	27	QRCFLC	28	2000	10	32	7	15
82180	27	QRCALB	13	2100	0	19	1	1
82180	27	QRCRBR	18	2100	40	26	6	18
82180	27	QRCVLT	13	2100	30	23	9	16
82180	27	QRCRBR	19	2200	0	28	0	0
82180	27	QRCFLC	8	2200	0	28	0	0
82280	16	QRCPRN	21	.	0	30	0	0
82280	16	QRCRBR	11	.	75	23	13	51
82280	16	QRCPRN	15	.	0	23	0	0

Table A-4 (cont.)

1980 MAST SURVEY

DATE	TRAIL	SPECIES	DBH	ELV	CANOPY	TWIG	TWIGACRN	ACORN
82280	16	QRCVLT	35	.	80	28	15	38
82280	16	QRCVLT	12	.	25	27	5	16
82280	16	QRCPRN	17	.	0	27	0	0
82280	16	QRCALB	10	.	0	24	0	0
82280	16	QRCVLT	9	.	85	29	20	54
82480	20	QRCRBR	38	.	90	35	20	55
82480	20	QRCRBR	28	.	85	29	15	49
82480	20	QRCVLT	20	.	20	30	2	2
82480	20	QRCRBR	16	.	90	26	21	108
82480	20	QRCPRN	28	.	0	34	0	0
82480	20	QRCALB	17	.	0	25	0	0
82480	20	QRCALB	24	.	5	30	0	0
82480	20	QRCRBR	26	.	40	26	4	9
82680	29	FGSGRN	12	5500	50	29	13	18
82680	29	FGSGRN	15	5500	30	31	11	14
82680	29	FGSGRN	10	5500	80	23	15	26
82680	29	FGSGRN	16	5500	60	30	13	20
82680	29	FGSGRN	12	5500	0	35	0	0
82680	29	FGSGRN	9	5500	0	33	0	0
82680	29	FGSGRN	13	5500	0	30	0	0
82680	29	FGSGRN	12	5500	0	32	0	0
82780	18	QRCPRN	16.	.	0	30	0	0
82780	18	QRCVLT	17	.	30	27	14	33
82780	18	QRCRBR	12	.	100	28	22	92
82780	18	QRCRBR	10	.	85	28	18	63
82780	18	QRCRBR	15	.	0	32	0	0
82780	18	QRCRBR	27	.	0	30	0	0
82780	18	QRCPRN	22	.	0	31	0	0
82780	18	CRYOVT	22	.	0	27	0	0
82880	34	QRCALB	30	1760	15	25	2	2
82880	34	QRCALB	14	1760	10	22	0	0
82880	34	QRCVLT	24	2000	100	35	32	111
82880	34	QRCVLT	13	2000	75	28	12	47
82880	34	QRCVLT	14	2000	80	25	15	44
82880	34	CRYTMN	16	2200	0	16	0	0
82880	34	FGSGRN	24	2200	0	24	0	0
82880	34	QRCALB	12	1920	0	21	0	0
82880	14	QRCPRN	25	.	0	26	0	0
82880	14	QRCRBR	9	.	60	19	10	26
82880	14	QRCPRN	13	.	0	24	0	0
82880	14	QRCPRN	22	.	0	30	0	0
82880	14	QRCPRN	18	.	0	20	0	0
82880	14	QRCPRN	13	.	0	28	0	0
82880	14	QRCPRN	12	.	0	26	0	0
82880	14	QRCPRN	9	4282	0	24	0	0
82980	23	QRCRBR	30	4200	80	24	10	39
82980	23	QRCALB	14	4200	0	27	0	0
82980	23	QRCRBR	24	4200	80	20	10	24
82980	23	CRYTMN	14	4200	60	14	8	41
82980	23	QRCVLT	24	4200	95	18	13	53
82980	23	QRCVLT	27	4200	80	15	9	30

Table A-4 (cont.)

1980 MAST SURVEY

DATE	TRAIL	SPECIES	DBH	ELV	CANOPY	TWIG	TWIGACRN	ACORN
82980	23	QRCVLT	35	4200	30	21	5	10
82980	23	QRCALB	18	4200	0	20	0	0
90180	31	QRCALB	24	3430	10	49	2	3
90180	31	QRCCCC	9	3860	.	49	31	125
90180	31	QRCRBR	12	4900	20	46	2	2
90180	31	QRCRBR	36	4990	80	39	4	8
90180	31	QRCRBR	14	3800	10	61	4	8
90180	31	QRCALB	26	4600	80	42	5	6
90180	31	QRCALB	18	4800	50	31	13	52
90180	31	QRCRBR	12	4790	40	29	4	4
90880	2	QRCPRN	20	.	0	26	0	0
90880	2	QRCPRN	18	.	0	20	0	0
90880	2	QRCRBR	13	.	80	33	16	51
90880	2	QRCCCC	20	.	100	27	24	123
90880	2	QRCPRN	52	.	0	20	0	0
90880	2	QRCRBR	18	.	80	19	15	63
90880	2	QRCRBR	14	.	30	25	6	19
90880	2	QRCPRN	20	.	0	19	0	0
91180	33	FGSGRN	14	5200	30	46	6	8
91180	33	QRCVLT	26	5000	0	29	0	0
91180	33	QRCVLT	32	5000	0	25	0	0
91180	33	QRCVLT	21	4700	0	24	0	0
91180	33	QRCVLT	20	4800	0	31	0	0
91180	33	QRCVLT	38	4750	0	27	0	0
91180	33	QRCRBR	23	4700	20	24	3	3
91180	33	QRCRBR	18	4700	10	25	2	2
90280	5	QRCPRN	16	.	0	35	0	0
90280	5	FGSGRN	17	.	0	41	0	0
90280	5	QRCVLT	13	.	0	29	0	0
90280	5	QRCRBR	25	.	90	20	19	121
90280	5	QRCPRN	9	.	0	27	0	0
90280	5	QRCPRN	15	.	0	21	0	0
90280	5	QRCPRN	17	.	0	25	0	0
90280	5	QRCRBR	14	.	30	26	7	7
83080	28	FGSGRN	19	5600	0	36	0	0
83080	28	FGSGRN	10	5100	0	32	0	0
83080	28	FGSGRN	11	5100	0	23	0	0
83080	28	QRCRBR	15	5100	0	23	0	0
83080	28	QRCPRN	16	4400	0	25	0	0
83080	28	FGSGRN	20	4300	0	37	0	0
83080	28	QRCRBR	27	3800	90	40	25	49
83080	28	FGSGRN	25	3200	0	31	0	0
82080	26	FGSGRN	15	.	80	35	20	61
82080	26	FGSGRN	15	.	60	30	10	29
82080	26	FGSGRN	17	5200	30	36	8	12
82080	26	QRCRBR	9	5000	0	30	0	0
82080	26	QRCRBR	14	5000	0	31	0	0
82080	26	QRCRBR	17	4860	60	29	12	51
82080	26	QRCRBR	11	4800	0	29	0	0
82080	26	QRCRBR	13	4800	90	32	28	188
81580	12	QRCPRN	25	.	0	25	0	0

Table A-4 (cont.)

81580	12	QRCPRN	22	.	0	25	0	0
81580	12	QRCFLC	10	.	80	28	20	72
81580	12	QRCRBR	10	.	10	27	3	13
81580	12	QRCVLT	17	.	0	22	0	0
81580	12	QRCVLT	21	.	60	22	14	48
8150	12	QRCRBR	12	.	10	20	1	3
81580	12	QRCVLT	14	.	45	31	7	8

Table A-5. 1981 GRSM mast survey data.

1981 MAST SURVEY

DATE	TRAIL	SPECIES	DBH	ELEV	CANOPY	TWIG	TWIGACRN	ACORN
91181	1	QRCALB	27	1600	100	83	75	268
91181	1	QRCALB	16	1400	90	38	20	37
91181	1	QRCCCC	13	1950	70	32	16	47
91181	1	QRCRBR	22	1600	25	46	14	46
91181	1	QRCPRN	32	1400	50	34	17	19
91181	1	QRCALB	26	1720	90	125	38	64
91181	1	QRCCCC	17	1900	50	54	26	43
91181	1	QRCFLC	17	1650	10	67	12	17
91081	27	QRCVLT	16	2040	0	61	0	0
91081	27	QRCALB	.	2045	0	53	0	0
91081	27	QRCVLT	.	2050	60	69	37	76
91081	27	QRCALB	.	2040	0	57	0	0
91081	27	QRCVLT	14	2090	80	60	34	73
91081	27	QRCALB	10	2100	30	57	21	36
91081	27	QRCVLT	16	2120	20	61	7	10
91081	27	QRCALB	30	2190	30	64	14	22
90981	22	FGSGRN	.	.	95	29	24	127
90981	22	QRCRBR	.	.	0	24	0	0
90981	22	QRCVLT	.	.	0	33	0	0
90981	22	QRCALB	.	.	40	31	18	40
90981	22	QRCPRN	.	.	65	26	20	40
90981	22	CRYCRD	.	.	40	20	8	13
90981	22	QRCPRN	.	.	0	27	0	0
90981	22	QRCRBR	.	.	20	24	4	7
91381	23	QRCVLT	22	.	0	133	0	0
91381	23	QRCPRN	18	.	50	142	47	76
91381	23	QRCRBR	18	.	0	115	0	0
91381	23	QRCPRN	14	.	30	85	10	13
91381	23	QRCVLT	23	.	0	81	0	0
91381	23	CRYTMN	14	.	65	58	17	20
91381	23	CRYTMN	15	.	80	41	21	32
91381	23	QRCVLT	19	.	15	80	6	6
90981	32	QRCRBR	20	.	15	36	10	16
90981	32	QRCRBR	18	.	5	30	3	4
90981	32	QRCALB	16	.	75	42	22	49
90981	32	QRCALB	15	.	95	48	32	152
90981	32	QRCPRN	16	.	90	34	18	84
90981	32	QRCALB	12	.	50	49	13	25
90981	32	CRYTMN	7	.	20	22	3	5
90981	32	CRYTMN	9	.	20	21	3	4
90981	34	QRCALB	.	1880	20	53	12	27
90981	34	QRCALB	19	2320	20	42	12	25
90981	34	QRCALB	12	2340	10	51	6	12
90981	34	QRCFLC	.	2440	80	56	31	61
90981	34	QRCALB	26	2600	30	47	12	17
90981	34	QRCPRN	24	2800	.	40	7	11
90981	34	QRCRED	30	3000	.	44	23	40
90981	34	QRCALB	29	2920	20	42	14	21
90981	31	QRCVLT	19	4800	10	46	2	3
90981	31	QRCRBR	18	4800	5	47	0	0
90981	31	QRCRBR	16	4800	10	44	3	3

Table A-5 (cont.)

1981 MAST SURVEY

DATE	TRAIL	SPECIES	DBH	ELEV	CANOPY	TWIG	TWIGACRN	ACORN
90981	31	QRCRBR	21	4800	0	38	0	0
90981	31	QRCRBR	22	4800	0	37	0	0
90981	31	QRCVLT	24	4800	.	30	1	3
90981	31	QRCRBR	22	4800	0	42	0	0
90981	31	QRCALB	16	4800	30	33	10	22
90981	17	CRYOVT	20	.	85	23	20	43
90981	17	QRCRBR	32	.	40	19	12	18
90981	17	QRCPRN	30	.	10	20	6	10
90981	17	QRCPRN	22	.	80	19	18	42
90981	17	QRCRBR	13	.	0	27	0	0
90981	17	QRCVLT	23	.	0	25	0	0
90981	17	QRCRBR	34	.	0	25	0	0
90981	17	QRCRBR	36	.	0	24	0	0
90981	28	QRCRBR	.	.	0	59	0	0
90981	28	QRCRBR	.	.	0	54	0	0
90981	28	QRCRBR	.	.	0	54	0	0
90981	28	QRCRBR	.	.	0	69	0	0
90981	28	QRCRBR	20	.	0	44	0	0
90981	28	QRCRBR	20	.	0	54	0	0
90981	28	QRCRBR	17	.	30	43	24	45
90981	28	QRCRBR	28	.	70	39	19	46
91181	26	QRCVLT	20	4925	0	43	0	0
91181	26	QRCVLT	18	4800	0	51	0	0
91181	26	QRCVLT	32	4625	0	48	0	0
91181	26	QRCPRN	11	4300	15	69	8	8
91181	26	QRCPRN	23	3850	30	55	21	40
91181	26	QRCRBR	10	3520	5	42	4	4
91181	26	QRCCCC	20	3260	90	38	35	126
91181	26	QRCALB	18	2950	5	61	1	1
90281	13	QRCPRN	14	.	85	60	33	77
90281	13	QRCCCC	14	.	25	48	8	18
90281	13	QRCALB	26	.	60	63	21	40
90281	13	CRYOVT	16	.	45	31	10	17
90281	13	QRCALB	33	.	90	60	36	121
90281	13	QRCPRN	29	.	90	49	37	95
90281	13	QRCRBR	18	.	80	47	33	83
90281	13	CRYGLB	40	.	70	45	20	37
83181	12	QRCPRN	22	.	50	35	14	30
83181	12	QRCVLT	17	.	0	34	0	0
83181	12	QRCPRN	17	.	85	34	20	57
83181	12	QRCALB	26	.	90	30	21	72
83181	12	QRCALB	23	.	5	26	3	6
83181	12	QRCVLT	12	.	0	34	0	0
83181	12	QRCALB	25	.	50	24	9	25
83181	12	QRCVLT	15	4075	0	38	0	0
91181	11	QRCRBR	22	.	0	56	0	0
91181	11	QRCPRN	18	.	70	49	20	31
91181	11	QRCPRN	11	.	40	67	5	5
91181	11	QRCCCC	14	.	60	36	16	34
91181	11	QRCVLT	19	.	10	28	3	3
91181	11	CRY	15	.	80	29	18	27

Table A-5 (cont.)

1981 MAST SURVEY

DATE	TRAIL	SPECIES	DBH	ELEV	CANOPY	TWIG	TWIGACRN	ACORN
90981	31	QRCRBR	21	4800	0	38	0	0
90981	31	QRCRBR	22	4800	0	37	0	0
90981	31	QRCVLT	24	4800	.	30	1	3
90981	31	QRCRBR	22	4800	0	42	0	0
90981	31	QRCALB	16	4800	30	33	10	22
90981	17	CRYOVT	20	.	85	23	20	43
90981	17	QRCRBR	32	.	40	19	12	18
90981	17	QRCPRN	30	.	10	20	6	10
90981	17	QRCPRN	22	.	80	19	18	42
90981	17	QRCRBR	13	.	0	27	0	0
90981	17	QRCVLT	23	.	0	25	0	0
90981	17	QRCRBR	34	.	0	25	0	0
90981	17	QRCRBR	36	.	0	24	0	0
90981	28	QRCRBR	.	.	0	59	0	0
90981	28	QRCRBR	.	.	0	54	0	0
90981	28	QRCRBR	.	.	0	54	0	0
90981	28	QRCRBR	.	.	0	69	0	0
90981	28	QRCRBR	20	.	0	44	0	0
90981	28	QRCRBR	20	.	0	54	0	0
90981	28	QRCRBR	17	.	30	43	24	45
90981	28	QRCRBR	28	.	70	39	19	46
91181	26	QRCVLT	20	4925	0	43	0	0
91181	26	QRCVLT	18	4800	0	51	0	0
91181	26	QRCVLT	32	4625	0	48	0	0
91181	26	QRCPRN	11	4300	15	69	8	8
91181	26	QRCPRN	23	3850	30	55	21	40
91181	26	QRCRBR	10	3520	5	42	4	4
91181	26	QRCCCC	20	3260	90	38	35	126
91181	26	QRCALB	18	2950	5	61	1	1
90281	13	QRCPRN	14	.	85	60	33	77
90281	13	QRCCCC	14	.	25	48	8	18
90281	13	QRCALB	26	.	60	63	21	40
90281	13	CRYOVT	16	.	45	31	10	17
90281	13	QRCALB	33	.	90	60	36	121
90281	13	QRCPRN	29	.	90	49	37	95
90281	13	QRCRBR	18	.	80	47	33	83
90281	13	CRYGLB	40	.	70	45	20	37
83181	12	QRCPRN	22	.	50	35	14	30
83181	12	QRCVLT	17	.	0	34	0	0
83181	12	QRCPRN	17	.	85	34	20	57
83181	12	QRCALB	26	.	90	30	21	72
83181	12	QRCALB	23	.	5	26	3	6
83181	12	QRCVLT	12	.	0	34	0	0
83181	12	QRCALB	25	.	50	24	9	25
83181	12	QRCVLT	15	4075	0	38	0	0
91181	11	QRCRBR	22	.	0	56	0	0
91181	11	QRCPRN	18	.	70	49	20	31
91181	11	QRCPRN	11	.	40	67	5	5
91181	11	QRCCCC	14	.	60	36	16	34
91181	11	QRCVLT	19	.	10	28	3	3
91181	11	CRY	15	.	80	29	18	27

Table A-5 (cont.)

1981 MAST SURVEY

DATE	TRAIL	SPECIES	DBH	ELEV	CANOPY	TWIG	TWIGACRN	ACORN
91181	11	QRCRBR	18	.	60	21	6	11
91181	11	QRCPRN	20	.	50	46	26	42
90181	3	QRCALB	13	1850	70	26	16	42
90181	3	QRCPRN	15	1850	60	53	13	26
90181	3	QRCALB	11	1850	10	54	4	7
90181	3	QRCPRN	16	1850	70	36	15	41
90181	3	QRCRBR	24	1850	10	53	3	3
90181	3	QRCCCC	11	1850	10	45	5	8
90181	3	QRCALB	16	1850	20	46	8	16
90181	3	QRCRBR	14	1850	20	35	4	4
90381	16	QRCVLT	41	.	80	16	15	64
90381	16	QRCRBR	25	.	40	24	8	16
90381	16	CRYOVT	20	.	65	17	13	36
90381	16	QRCPRN	22	.	70	13	11	32
90381	16	QRCVLT	35	.	20	20	7	13
90381	16	QRCALB	10	.	10	27	9	14
90381	16	QRCFLC	13	.	40	25	12	19
90381	16	QRCVLT	9	.	0	26	0	0
92081	7	QRCPRN	19	1800	100	108	62	103
92081	7	QRCPRN	13	2600	90	59	28	67
92081	7	QRCMRL	13	1700	70	80	48	62
92081	7	QRCCCC	15	1860	50	50	16	22
92081	7	QRCALB	27	2600	50	91	27	35
92081	7	QRCPRN	29	1700	100	89	48	115
92081	7	QRCVLT	16	1100	80	104	81	308
92081	7	QRCVLT	21	1640	80	72	51	141
92081	7	QRCVLT	21	1640	80	72	51	141
90381	6	QRCRBR	22	2800	95	58	48	163
90381	6	QRCPRN	24	2800	20	45	10	15
90381	6	QRCALB	19	2750	70	48	26	62
90381	.	QRCVLT	30	2750	70	37	22	48
90381	6	CRY	20	2750	0	42	0	0
90381	6	QRCPRN	26	2750	40	56	14	21
90381	6	QRCVLT	22	2750	80	43	30	71
90381	6	QRCALB	11	2600	.	50	0	0
90781	33	QRCVLT	.	4945	0	37	0	0
90781	33	QRCRED	.	4740	5	32	0	0
90781	33	QRCRED	.	4640	0	36	0	0
90781	33	QRCVLT	.	4480	5	35	1	3
90781	33	QRCRED	10	4440	0	38	0	0
90781	33	QRCRED	30	4640	15	37	4	9
90781	33	QRCRED	16	4840	10	33	2	4
90781	33	QRCRED	21	4960	10	26	3	6

Table A-6. 1982 GRSM mast survey data

1982 MAST SURVEY

DATE	TRAIL	SPECIES	DBH	ELEV	CANOPY	TWIG	TWIGACRN	ACORN
90482	23	QRCRBR	28	4072	14	34	4	5
90482	23	QRCALB	28	4200	20	20	3	3
90482	23	CRYOVT	18	4200	20	20	5	10
90482	23	QRCALB	24	4400	40	20	12	21
90482	23	QRCVLT	34	5100	30	25	10	17
90482	23	QRCRBR	29	5300	30	19	5	10
90482	23	QRCFLC	26	5200	10	25	5	10
90482	23	FGSGRN	20	5128	0	15	0	0
90382	11	QRCRBR	10	2400	30	29	3	4
90382	11	QRCPRN	28	2520	.	38	1	1
90382	11	QRCVLT	16	2540	70	43	13	32
90382	11	QRCRBR	25	2700	0	45	0	0
90382	11	QRCPRN	26	2740	0	40	0	0
90382	11	QRCRBR	30	1720	0	38	0	0
90382	11	QRCCCC	12	1920	40	56	13	30
90382	11	QRCALB	19	1566	.	45	0	0
82682	12	QRCPRN	26	2200	0	27	0	0
82682	12	QRCPRN	33	2560	0	34	0	0
82682	12	QRCRBR	35	3000	40	29	10	18
82682	12	QRCVLT	22	3480	5	41	1	1
82682	12	QRCALB	43	3883	0	34	0	0
82682	12	QRCRBR	15	3840	35	31	11	12
82682	12	QRCRBR	23	4037	0	31	0	0
82682	12	QRCVLT	17	4077	0	39	0	0
82782	4	QRCFLC	21	1800	35	43	5	8
82782	4	QRCALB	32	1800	0	59	0	0
82782	4	JGLNGR	33	1800	0	27	0	0
82782	4	QRCSTL	32	1800	0	52	0	0
82782	4	QRCVLT	34	1800	40	68	11	17
82782	4	QRCALB	60	1800	10	50	3	3
82782	4	CRYOVT	18	1800	0	28	0	0
82782	4	QRCALB	24	1800	0	62	0	0
82882	3	QRCALB	12	.	10	76	1	2
82882	3	QRCALB	24	.	0	79	0	0
82882	3	QRCFLC	.	.	70	79	63	167
82882	3	QRCPRN	.	.	10	61	1	1
82882	3	CRYTMN	24	.	10	69	1	1
82882	3	QRCRBR	.	.	80	43	6	10
82882	3	QRCVLT	.	.	90	41	21	40
82882	3	QRCALB	18	.	0	70	0	0
82982	16	QRCPRN	36	2300	0	61	0	0
82982	16	QRCRBR	28	2580	40	52	12	25
82982	16	QRCRBR	25	2620	0	96	0	0
82982	16	CRYGLB	18	3000	0	58	0	0
82982	16	QRCPRN	11	3090	0	96	0	0
82982	16	QRCCCC	13	3300	25	115	1	1
82982	16	QRCALB	10	4480	0	87	0	0
82982	16	QRCRED	9	4597	100	121	43	60
90582	24	ASCOCT	.	.	90	17	5	7
90582	24	QRCRBR	.	.	0	100	0	0
90582	24	JGLNGR	.	.	0	100	0	0

Table A-6 (cont.)

1982 MAST SURVEY

DATE	TRAIL	SPECIES	DBH	ELEV	CANOPY	TWIG	TWIGACRN	ACORN
90582	24	QRCALB	.	.	0	100	0	0
90582	24	JGLNGR	.	.	0	100	0	0
90582	24	QRCVLT	.	.	0	100	0	0
90582	24	QRCALB	.	.	0	100	0	0
90582	24	QRCCCC	.	.	0	100	0	0
81482	33	QRCRBR	9	5000	0	100	0	0
81482	33	QRCRBR	10	4920	0	100	0	0
81482	33	QRCPRN	9	4650	0	100	0	0
81482	33	QRCRBR	12	4560	0	100	0	0
81482	33	QRCRBR	13	4480	0	100	0	0
81482	33	QRCRBR	12	4520	0	100	0	0
81482	33	QRCRBR	9	4660	0	100	0	0
81482	33	QRCALB	12	4820	0	100	0	0
90782	27	QRCALB	22	2040	0	29	0	0
90782	27	QRCVLT	41	2045	70	32	10	23
90782	27	QRCRBR	7	2050	40	40	5	18
90782	27	QRCVLT	15	2100	30	44	6	7
90782	27	QRCRBR	22	2110	10	30	2	2
90782	27	QRCRBR	20	2170	60	40	15	34
90782	27	JGL	12	2180	0	31	0	0
90782	27	QRCALB	31	2190	0	43	0	0
82882	25	QRCPRN	11	2500	0	111	0	0
82882	25	QRCRBR	23	3020	0	83	0	0
82882	25	QRCPRN	16	3300	10	165	5	5
82882	25	QRCPRN	16	3540	0	69	1	1
82882	25	QRCVLT	14	2600	60	121	14	20
82882	25	QRCCCC	13	3100	0	184	7	8
82882	25	QRCRBR	25	3400	0	151	0	0
82882	25	QRCRBR	21	3680	0	115	0	0
90982	17	QRCPRN	12	.	0	43	1	1
90382	35	QRCRED	.	.	80	31	26	64
90382	35	QRCALB	.	.	0	32	4	4
90382	35	QRCRED	.	.	35	30	13	44
90382	35	QRCPRN	.	.	40	23	7	12
90382	35	QRCVLT	.	.	1	35	4	7
90382	35	QRCPRN	.	.	0	41	0	0
90382	35	QRCCCC	.	.	2	29	1	2
90382	35	QRCALB	.	.	0	38	0	0
90982	31	QRCRED	21	.	5	30	2	2
90982	31	QRCRED	24	.	2	36	1	1
90982	31	QRCRED	9	.	40	28	14	39
90982	31	QRCALB	22	.	0	24	0	0
90982	31	QRCALB	28	.	0	34	0	0
90982	31	CRY	25	.	2	19	0	0
90982	31	QRCRED	24	.	0	29	0	0
90982	31	QRCRED	16	.	0	36	0	0
91682	5	QRCRBR	22	3940	0	28	0	0
91682	5	QRCPRN	16	3840	0	39	0	0
91682	5	QRCRBR	27	3000	5	54	2	3
91682	5	QRCPRN	30	2040	5	38	1	1
91682	5	QRCPRN	14	2920	0	33	0	0

Table A-6 (cont.)

1982 MAST SURVEY

DATE	TRAIL	SPECIES	DBH	ELEV	CANOPY	TWIG	TWIGACRN	ACORN
91682	5	QRCPRN	32	2540	0	31	0	0
91682	5	QRCRBR	42	2400	0	44	0	0
91682	5	QRCRBR	36	1840	80	55	5	8
90582	6	QRCRBR	20	2548	0	35	0	0
90582	6	QRCRBR	12	2760	0	52	0	0
90582	6	QRCPRN	24	2660	0	41	1	2
90582	6	QRCRBR	10	2776	0	35	0	0
90582	6	QRCPRN	14	2720	0	40	0	0
90582	6	CRY	18	2660	0	43	0	0
90582	6	QRCCCC	22	2760	0	35	0	0
90582	6	QRCALB	16	2767	0	38	0	0
90782	1	QRCPRN	17	1440	0	89	0	0
90782	1	QRCRBR	16	1540	0	36	0	0
90782	1	QRCRBR	14	1660	0	44	1	1
90782	1	QRCRBR	15	1800	80	26	11	35
90782	1	QRCCCC	17	1760	30	43	6	11
90782	1	QRCRBR	26	1720	.	78	0	0
90782	1	QRCALB	18	1862	0	40	0	0
90782	1	QRCRBR	11	1920	0	48	0	0
82882	2	QRCCCC	9	2800	0	46	0	0
82882	2	QRCFLC	16	2900	0	37	2	2
82882	2	QRCPRN	24	3220	0	38	2	2
82882	2	QRCRBR	32	3600	0	32	0	0
82882	2	QRCRBR	20	4120	0	30	0	0
82882	2	QRCRBR	10	4220	0	28	0	0
82882	2	QRCCCC	32	4640	0	33	0	0
82882	2	QRCRBR	50	4840	0	37	0	0
90382	32	QRCALB	23	2275	10	54	1	1
90382	32	QRCRBR	12	2250	80	32	17	41
90382	32	QRCVLT	16	2250	50	25	11	30
90382	32	QRCFLC	18	2200	100	25	22	129
90382	32	QRCRBR	18	2125	40	25	5	12
90382	32	QRCFLC	18	2150	80	33	10	27
90382	32	QRCFLC	20	2150	20	26	8	15
90382	32	QRCALB	21	2125	0	28	1	1
90382	20	QRCRBR	17	4200	0	75	0	0
90382	20	QRCRBR	22	4140	0	63	0	0
90382	20	QRCRBR	36	3850	0	81	0	0
90382	20	FGSGRN	19	3560	0	215	0	0
90382	20	QRCRBR	20	4150	0	76	0	0
90382	20	QRCPRN	28	4040	0	104	0	0
90382	20	QRCRBR	42	3600	0	111	0	0
90382	20	QRCALB	25	3500	10	131	0	0
90382	34	QRCALB	28	1751	0	39	0	0
90382	34	QRCALB	19	1880	0	31	0	0
90382	34	QRCRBR	.	2040	0	26	0	0
90382	34	QRCFLC	27	2360	40	26	7	25
90382	34	QRCVLT	30	2340	50	34	16	38
90382	34	QRCRBR	21	2380	90	28	20	53
90382	34	QRCPRN	23	.	0	39	0	0
90382	34	QRCALB	13	.	10	34	1	1

Table A-6 (cont.)

82682	28	QRCRBR	24	4750	30	75	2	2
82682	28	QRCRBR	16	4380	50	80	10	18
82682	28	QRCRBR	15	4040	0	58	0	0
82682	28	QRCRBR	24	3840	10	48	2	2
82682	28	QRCPRN	23	3650	0	37	0	0
82682	28	QRCRBR	20	3250	0	43	0	0
82682	28	QRCVLT	11	2980	90	54	25	74
82682	28	QRCALB	13	2980	0	45	0	0

Table A-7. SAS Program to input mast survey data.

```
DATA MASTDAT;
INPUT DATE TRAIL
      #2  SPECIES & CANOPY DBH ELEV
      #3  TWIG    TWIGACRN    ACORN;
CARDS;
(data should be entered here)
;
PROC PRINT;
TITLE (year)   MAST SURVEY
VAR  TRAIL  SPECIES  DBH  ELEV  CANOPY  TWIG
     TWIGACRN  ACORN;
ID DATE;
DATA __ NULL__;
SET MASTDAT;
FILE DDI;
PUT DATE 1-6   TRAIL 8-9   SPECIES 11-16   DBH 18-19
    CANOPY 26-28   TWIG 30-32   TWIGACRN 34-36   ACORN 38-40;
```

Table A-8. SAS program MAST.SAS

```
OPTIONS LINESIZE=79;
TITLE MAST INDEX FOR 1980;
DATA MAST;
INPUT DATE TRAIL #2 SPECIES $ CANOPY DBH ELEV #3 TWIG TWIGACRN ACORN;
IF CANOPY=. OR TWIG=. OR TWIGACRN=. OR ACORN=. THEN DELETE;
TBA=TWIGACRN/TWIG*100;
APT=ACORN/TWIG;
IF CANOPY<6 THEN PCPA=1;
IF CANOPY>=6 AND CANOPY<34 THEN PCPA=2;
IF CANOPY>=34 AND CANOPY<67 THEN PCPA=3;
IF CANOPY>=67 THEN PCPA=4;
IF TBA<6 THEN PTBA=1;
IF TBA>=6 AND TBA<34 THEN PTBA=2;
IF TBA>=34 AND TBA<67 THEN PTBA=3;
IF TBA>=67 THEN PTBA=4;
IF APT<1 THEN AAPT=1;
IF APT>=1 AND APT<3 THEN AAPT=2;
IF APT>=3 AND APT<5 THEN AAPT=3;
IF APT>=5 AND APT<7 THEN AAPT=4;
IF APT>=7 THEN AAPT=5;
CARDS;
PROC FORMAT;
VALUE CATFMT 1=1 2=2 3=3 4=4 5=5;
PROC SORT; BY SPECIES;
PROC FREQ;
TABLE PCPA / OUT=A;
TABLE PTBA / OUT=B;
TABLE AAPT / OUT=C;
FORMAT PCPA CATFMT. PTBA CATFMT. AAPT CATFMT.;
BY SPECIES;
PROC MEANS DATA=MAST NOPRINT N; VAR CANOPY; BY SPECIES;
OUTPUT OUT=NUMBER N=NUMBER;
PROC SORT DATA=NUMBER; BY SPECIES;
DATA AA; SET A; RENAME PCPA=ID COUNT=CPCPA;
DATA BB; SET B; RENAME PTBA=ID COUNT=CPTBA;
DATA CC; SET C; RENAME AAPT=ID COUNT=CAAPT;
PROC SORT DATA=AA; BY SPECIES ID;
PROC SORT DATA=BB; BY SPECIES ID;
PROC SORT DATA=CC; BY SPECIES ID;
DATA ALL; SET AA BB CC; BY SPECIES ID;
IF CPCPA=. THEN CPCPA=0;
IF CPTBA=. THEN CPTBA=0;
IF CAAPT=. THEN CAAPT=0;
SUM=CPCPA+CPTBA+CAAPT;
VAL=SUM*(ID-1);
PROC SORT; BY SPECIES;
PROC MEANS NOPRINT SUM; VAR VAL; BY SPECIES;
OUTPUT OUT=D SUM=NUMER;
PROC SORT DATA=D; BY SPECIES;
DATA INDEX; MERGE D NUMBER; BY SPECIES; INDEX=NUMER/NUMBER;
PROC PRINT; ID SPECIES; VAR INDEX;
```

Table A-9. Hard mast survey data from 1983 observer bias study.

DATE	TRAIL	SPECIES	DBH	ELEV	CANOPY	TWIG	TWIGACRN	ACORN
83183	16	QRCRBR	14	4590	0	118	2	2
83183	16	QRCPRN	15	4320	0	159	0	0
83183	16	QRCPRN	18	4100	10	147	10	11
83183	16	QRCCCC	24	3775	0	80	2	3
83183	16	QRCPRN	17	3450	15	139	8	13
83183	16	QRCCCC	12	3075	0	198	0	0
83183	16	QRCPRN	24	2700	0	120	0	0
83183	16	QRCRBR	13	2650	0	183	0	0
90283	17	FGSGRN	14	4575	40	107	22	24
90283	17	QRCRBR	17	4400	5	92	5	6
90283	17	QRCRBR	49	4200	50	96	9	10
90283	17	QRCPRN	23	4050	5	102	3	3
90283	17	QRCRBR	17	3800	0	91	0	0
90283	17	QRCRBR	23	3620	0	107	1	2
90283	17	QRCRBR	33	3350	0	83	2	2
90283	17	QRCRBR	15	3100	20	91	14	16
90183	26	FGSGRN	20	4850	40	148	41	42
90183	26	QRCRBR	20	4900	15	190	10	15
90183	26	QRCRBR	20	4950	5	151	4	4
90183	26	FGSGRN	15	4980	30	148	32	32
90183	26	FGSGRN	11	5025	70	116	56	65
90183	26	FGSGRN	18	5150	60	103	41	43
90183	26	FGSGRN	16	5200	90	142	79	84
90183	26	FGSGRN	11	5275	15	122	10	10
82983	12	QRCRBR	17	4077	0	166	0	0
82983	12	QRCALB	10	3975	5	113	4	5
82983	12	QRCPRN	16	3840	0	79	1	1
82983	12	QRCPRN	20	3800	5	119	2	2
82983	12	QRCALB	17	3725	0	117	1	2
82983	12	QRCALB	14	3475	5	127	3	4
82983	12	QRCPRN	11	3175	40	94	5	5
82983	12	QRCCCC	12	3200	0	107	0	0
83083	23	QRCRBR	16	4500	15	168	5	12
83083	23	QRCRBR	20	4480	25	192	15	28
83083	23	CRYTMN	21	4360	20	163	12	12
83083	23	QRCALB	25	4275	5	177	2	3
83083	23	QRCRBR	20	4400	40	121	15	32
83083	23	QRCALB	26	4440	5	128	3	5
83083	23	QRCRBR	16	4270	25	137	13	31
83083	23	QRCPRN	21	4200	5	103	6	6
90283	17	CRYTMN	11	2520	0	43	0	0

Table A-9 (cont.)

DATE	TRAIL	SPECIES	DBH	ELEV	CANOPY	TWIG	TWIGACRN	ACORN
90283	17	QRCRBR	18	3100	0	110	0	0
90283	17	QRCPRN	48	3310	1	87	4	4
90283	17	QRCRBR	21	3610	0	97	0	0
90283	17	QRCRBR	27	3800	0	91	0	0
90283	17	QRCRBR	21	4020	0	109	0	0
90283	17	QRCRBR	15	4200	0	74	0	0
90283	17	QRCRBR	68	4100	0	82	0	0
90283	17	QRCRBR	19	3980	0	81	0	0
83083	23	CRYCRD	11	4430	15	51	11	15
83083	23	QRCALB	30	4420	12	190	24	35
83083	23	QRCRBR	9	4430	0	109	0	0
83083	23	QRCALB	18	4460	0	100	0	0
83183	16	QRCPRN	15	2800	0	65	0	0
83183	16	QRCPRN	18	3360	10	90	2	5
83183	16	QRCALB	11	4180	0	112	0	0
83183	16	QRCRBR	9	4520	0	81	0	0
82883	12	QRCPRN	9	2180	1	44	2	2
82883	12	QRCVLT	10	3600	0	98	0	0
82883	12	QRCVLT	10	3800	0	61	0	0
82883	12	QRCALB	24	3690	5	42	1	1
90183	26	QRCRBR	9	5190	0	152	0	0
90183	26	FGSGRN	15	5100	10	168	50	63
90183	26	QRCRBR	12	4990	1	77	1	1
90183	26	QRCRBR	15	4920	0	77	1	1
90183	26	QRCRBR	20	4900	0	132	0	0
90183	26	QRCALB	10	4900	1	122	2	3
90183	26	FGSGRN	12	4800	0	58	0	0
90183	26	QRCRBR	17	4910	0	119	0	0

Table A-9 (cont.)

DATE	TRAIL	SPECIES	DBH	ELEV	CANOPY	TWIG	TWIGACRN	ACORN
90283	17	QRCPRN	35	2900	1	168	0	0
90283	17	QRCRBR	17	3220	0	119	0	0
90283	17	QRCRBR	49	3520	70	115	17	49
90283	17	QRCPRN	16	3880	5	146	4	6
90283	17	QRCRBR	14	4240	1	214	1	1
90283	17	FGSGRN	17	4580	40	164	29	40
90283	17	FGSGRN	12	5040	25	174	12	12
90183	26	FGSGRN	16	5300	10	135	4	4
90183	26	FGSGRN	15	5200	70	144	49	56
90183	26	FGSGRN	15	5100	35	147	26	27
90183	26	FGSGRN	15	5000	25	131	4	4
90183	26	QRCRBR	19	4950	2	135	1	1
90183	26	QRCRBR	12	4900	1	102	0	0
90183	26	FGSGRN	15	4840	15	134	15	17
90183	26	FGSGRN	15	4740	20	149	23	28
83183	16	QRCRBR	25	2630	1	131	3	3
83183	16	QRCPRN	12	2960	5	161	2	4
83183	16	QRCPRN	37	3300	2	159	5	7
83183	16	QRCRBR	20	3680	0	203	0	0
83183	16	CRYTMN	12	3900	0	96	0	0
83183	16	QRCPRN	20	4130	2	177	2	4
83183	16	QRCPRN	19	4320	5	177	4	5
83183	16	QRCRBR	9	4597	5	208	5	10
83083	23	FGSGRN	12	4150	0	202	0	0
83083	23	QRCRBR	17	4300	1	185	1	1
83083	23	CRYTMN	16	4480	20	149	17	30
83083	23	QRCALB	16	4440	12	190	11	12
83083	23	QRCRBR	57	4360	5	172	6	8
83083	23	CRYTMN	57	4480	0	112	0	0
83083	23	QRCRBR	15	4520	70	194	49	147
83083	23	QRCPRN	10	4700	2	244	4	2
82983	12	QRCPRN	19	3100	0	190	0	0
82983	12	QRCRBR	19	3400	2	143	3	4
82983	12	QRCPRN	17	3500	0	192	0	0
82983	12	QRCCCC	12	3600	0	113	0	0
82983	12	QRCALB	13	3800	1	207	1	1
82983	12	QRCRBR	38	3760	60	211	19	32
82983	12	QRCPRN	12	3940	0	326	1	1
82983	12	QRCALB	25	4040	5	219	3	7

Table A-10. TWRA hard mast species code sheet.

Code Number	Common Name	Scientific Name
	White Oaks	
01	White Oak	Quercus alba
02	Chestnut Oak	Quercus prinus
03	Post Oak	Quercus stellata
04	Chinkapin Oak	Quercus muehlenbergii
05	Swamp White Oak	Quercus bicolor
10	Swamp Chestnut Oak (Cow Oak)	Quercus michauxii
11	Overcup Oak	Quercus lyrata
12	Bur Oak	Quercus macrocarpa
	Red Oaks	
20	Northern Red Oak	Quercus rubra
21	Southern Red Oak	Quercus falcata
22	Cherrybark Oak	Quercus falcata pagodaefolia
23	Scarlet Oak	Quercus coccinea
24	Black Oak	Quercus velutina
25	Blackjack Oak	Quercus marilandica
26	Shumard Oak	Quercus shumardii
30	Willow Oak	Quercus phellos
31	Water Oak	Quercus nigra
32	Shingle Oak	Quercus imbricaria
33	Pin Oak	Quercus palustris
34	Unifentified Red Oaks	
	Hickories	
40	Unidentified Hickory	
41	Bitternut Hickory	Carya cordiformis
42	Mockernut Hickory	Carya tomentosa
43	Shellbark Hickory	Carya laciniosa
44	Shagbark Hickory	Carya ovata
45	Pignut Hickory	Carya glabra
	Pecans	
50	Sweet Pecan	Carya illinoensis
51	Water Pecan	Carya aquatica
	Walnut	
60	Unidentified Walnut	
61	Black Walnut	Juglans nigra
62	Butter Nut	Juglans cinerea
	Beech	
70	Beech	Fagus grandifolia

APPENDIX B. Instructions and data sheets for GRSM hard mast survey.

Table B-1. Schedule for GRSM hard mast survey.

AUGUST		Labor
1st week	Mast survey project leader plans training session, choses routes for the year, recruits surveyors	(1) x 1/2 day
	- Training session given by project leader, participation of data collectors	(4) x 1/2 day
1st & 2nd week	- Mast survey starts. Only one data collector necessary per route, very easy field work. Approximately 3 persons needed to survey. Data collectors turn in survey sheets and maps to project leader at end of sampling period.	(3) x 8-1/2 days
3rd week	- Data is proofed and entered into the computer. Mast indices calculated.	(1) x 1 day
	- Short report written by project leader about mast yields of GRSM. Copies sent to District Rangers, Resources Management staff, Uplands Field Research Laboratory staff, and TWRA.	

Total labor commitment to mast survey annually: 30 workdays.

Table B-2. Guidelines for sampling routes and sampling points.

1. Sampling routes. The larger the sample size, the greater the confidence that can be placed in the calculated mast index. We have selected thirty 4.0 mi (6.4 km) trail sections for the hard mast survey based on the following criteria:

    (1) Representation of hard mast species

    (2) Even geographic distribution within the park

    (3) Distribution in three elevational classes (low, mid-, and high elevations)

    The following 30 trails in eight subdistricts should be sampled:

Chilhowee	Cades Cove
1	2
7	3
8	4
	5

Little River	Cosby
9	16
11	17
12	18
13	19
14	
15	

Cataloochee	Oconaluftee
23	26
25	27
	28
	29
	30
	40

Lake	Twentymile
32	34
33	35
	36

Table 3 of this appendix lists the codes and names of these trails.

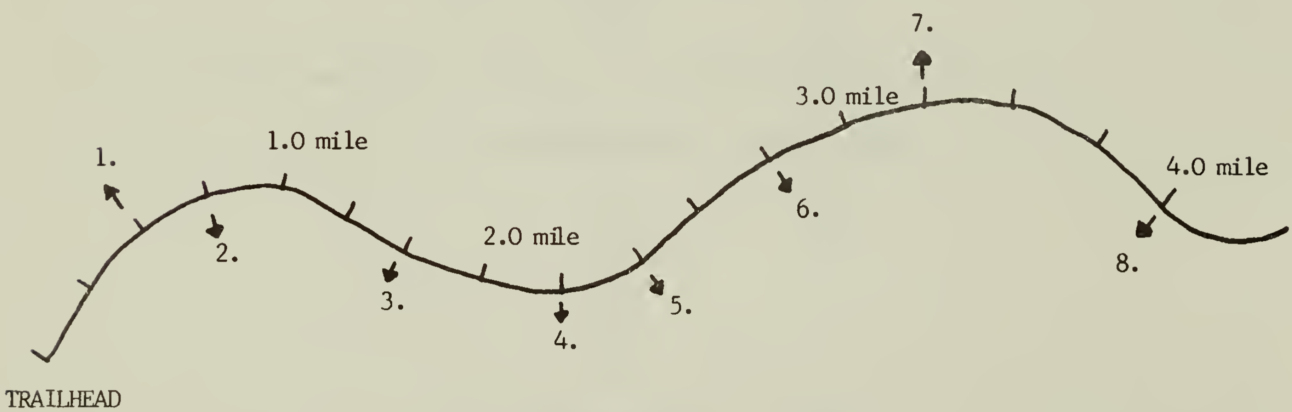
We have included only three high-elevation trail routes, primarily to provide a sample of beech mast. We have included 15 low elevation and 12 mid-elevation trail routes. Oaks predominate on these trail sections.

Each 4.0-mi (6.4 km) trail segment required about 2 to 4 hrs of hiking, and the 8 points required a total of 2 to 3 hrs of sampling. With driving time to

Table B-2 (cont.)

trailheads, the routes thus require 1 man-day of effort, and the full sampling program requires 30 man-days. Ideally, the sampling will span no more than 2 weeks. Thus a minimum of 3 samples are required each sampling day. Of the 30 routes, 9 are along roads and can probably be sampled in 25-1/2 man-days. In the past, samplers have worked in pairs. However, this does not seem to be an efficient use of available manpower. It is important that the samplers of the mast routes along roads be instructed to survey at least 10 m from the roadside.

2. Sampling points. Each 4.0 mile (6.4 km) route should be marked off in .25 mi (400 m) segments on photocopied USGS 7.5' quadrangle maps. Starting at .25 mi (400 m) from the trailhead, one out of every two of these points is randomly chosen for sampling. This is accomplished by a random numbers table or coin toss. For example, "heads" would mean sampling the first of each pair of points; "tails," the second. Alternatively, an odd random number would mean sampling the first point and an even number, the second. Then a second random number of coin toss is used to establish the side of the route to be sampled. For example, "heads" or "odd" would mean left, and "tails" or "even" would mean right. The project leader should accomplish this process of sample point selection before the survey, and the sampling points should be marked clearly on photocopies of topographic maps to be used in the field. Here is an illustration:



Coin tosses in 8 pairs, totaling 16, determined this sampling scheme as follows:

1. TH	5. HT
2. HT	6. HT
3. TT	7. HH
4. TT	8. TT

Table B-3. Hard mast survey routes

Code	Trail
	Chilhowee
1	U.S. 129 from Parson Branch Road to Deal Gap (1600-2000 ft)
2	Parson Branch Road to Bunker Hill old fire tower (2550-2770 ft)
7	Foothills Parkway (4 mile section) (2000-2600 ft)
8	Rabbit Creek starting at Abrams Creek - then take connecting trail to Abrams Fall trail (1200-2000 ft)
	Cades Cove
2	Gregory Bald trail from Sams Gap (2800-5000 ft)
3	Rich Mountain Road from Loop Road (1800-2550 ft)
4	Cades Cove Loop Road from Sparks to Hyatt Lane on both sides (1800 ft)
5	Bote Mountain Road from Spence Field (2600-4900 ft)
	Little River
10	Boundary trail from Tremont entrance toward Schoolhouse Gap (1200-2200 ft)
11	Meigs Mountain from Metcalf Bottoms to Sinks trail (2950-4100 ft)
12	Cove Mountain from Holy Butt to Cove Mountain Tower (2950-4100 ft)
13	Old Sugarlands to Cherokee Orchard and Roaring Fork (1500-2600 ft)
14	Cherokee Orchard and Bullhead (2800-2550 ft)
15	AT from Newfound Gap toward Ice Water Springs shelter) (5040-6030 ft)
	Cosby
16	Greenbrier Pinnacle trail from New Bridge to tower (2640-4600 ft)
17	Cosby campground to Low Gap (2450-4240 ft)
18	Lower White Rock trail from Cosby campground (2400-3600 ft)
19	Boundary trail west from Greenbriar cove (1700-3000 ft)
	Cataloochee
20	Pig Pen trail (Long Bunk) from Mount Sterling Gap (3900-4100 ft)
22	Pretty Hollow Gap trail from Pretty Hollow Gap (3000-5200 ft)
23	Cataloochee Divide from Cove Creek Gap (4100-4700 ft)
24	Cataloochee Loop Road (2600-2700 ft)
25	NC284 to Mount Sterling Gap (2500-3900 ft)
	Oconaluftee
26	Heintooga-Round Road from Balsam Mountain campground (4700-5300 ft)
27	US441 from Smokemont to Oconaluftee Visitor Center (2100-3000 ft)
28	Kephart Prong trail from Richland Mountain trail to US441 (2700-5300 ft)
29	Clingmans Dome to Silers Bald (2700-5300 ft)
30	Thomas Divide starting at Newfound Gap Road (4600-5000 ft)
40	Heintooga-Round Road from Oak Gap (4400-3400 ft)

Table B-3 (cont.)

Code	Trail
	Lake
31	Thomas Divide from Newton Bald to Deeplow Gap (2900-5000 ft)
32	NC 9A from Hickory Flats to end of road (2200 ft)
33	Welch Ridge from Mule Gap to Mount Glory (4400-5600 ft)
	Twenty-Mile
34	Pilkey Creek from Fontana Lake toward Hazel Creek Junction (1800-3200 ft)
35	Twenty-Mile Ranger Station toward Sassafras Gap (1300-3400 ft)
36	Lakeshore trail from Fontana Dam to Campsite 90 (2000-2400 ft)

Table B-4. Field survey checklist

BEFORE SAMPLING

1. Check for equipment
    a. Binoculars
    b. Pencils
    c. Data sheet
    d. Clipboard
    e. DBH tape
    f. USGS topographic map with mast route highlighted
    g. Altimeter (make sure the altimeter is set to correct elevation)

2. Complete certain portions of data sheet
    a. Name of surveyor
    b. Date
    c. County and area
    d. Make sure mast survey leader has marked the route number on the data sheet

ON ARRIVAL AT MAST ROUTE

1. Walk to sampling point marked on your topography map
2. Find the closest hard mast tree that is at least 30.5 cm (12 in) and no larger than 80 cm (30 in) dbh. The tree crown must be intact.
3. Check with topographic map and altimeter to determine your position. Always number sampling points on map in order.
4. Record species name.
5. Record elevation (in ft).
6. Record dbh (in cm).
7. Lie down under mast tree.
    a. Using binoculars, survey tree crown as if a one-dimensional cross-section and estimate the percent of visible crown with seeds. Record which of 5 categories has an average value (10%, 30%, 50%, 70%, or 90%) that is closest to your estimate.
    b. Randomly select 5 visible terminal limbs approximately 1 m (3 ft) long in the productive crown. For each limb, record the number of twigs, number of twigs with seeds, and total number of seeds.
8. Record any pertinent observations. Note seed quality, if seed drop has been initiated, if wildlife observed feeding on mast, etc.
9. Repeat steps 1 to 8 for a total of 8 trees per route.

AFTER SURVEYING IS COMPLETED

1. Clip topographic map to data sheet and promptly turn in to the mast survey leader.

Table B-5. Revised hard mast survey.

Date ____________ Area ____________ County ____________

#1

Species			GRSM Code:		
			TWRA code:		
# Crown w/acorns		Limb #	# Twig	# Twig w/acorns	Total acorns
0-20:		1			
21-40:		2			
41-60:		3			
61-80		4			
81-100		5			
		Total			
DBH:			Elevation		

#2

Species			GRSM Code:		
			TWRA code:		
# Crown w/acorns		Limb #	# Twig	# Twig w/acorns	Total acorns
0-20:		1			
21-40:		2			
41-60:		3			
61-80		4			
81-100		5			
		Total			
DBH:			Elevation		

#3

Species			GRSM Code:		
			TWRA code:		
# Crown w/acorns		Limb #	# Twig	# Twig w/acorns	Total acorns
0-20:		1			
21-40:		2			
41-60:		3			
61-80		4			
81-100		5			
		Total			
DBH:			Elevation		

#4

Species			GRSM Code:		
			TWRA code:		
# Crown w/acorns		Limb #	# Twig	# Twig w/acorns	Total acorns
0-20:		1			
21-40:		2			
41-60:		3			
61-80		4			
81-100		5			
		Total			
DBH:			Elevation		

#5

Species			GRSM Code:		
			TWRA code:		
# Crown w/acorns		Limb #	# Twig	# Twig w/acorns	Total acorns
0-20:		1			
21-40:		2			
41-60:		3			
61-80		4			
81-100		5			
		Total			
DBH:			Elevation		

#6

Species			GRSM Code:		
			TWRA code:		
# Crown w/acorns		Limb #	# Twig	# Twig w/acorns	Total acorns
0-20:		1			
21-40:		2			
41-60:		3			
61-80		4			
81-100		5			
		Total			
DBH:			Elevation		

Table B-5 (cont.)

#7

Species			GRSM Code: TWRA code:		
# Crown w/acorns		Limb #	# Twig	# Twig w/acorns	Total acorns
0-20:		1			
21-40:		2			
41-60:		3			
61-80		4			
81-100		5			
		Total			
DBH:			Elevation		

#8

Species			GRSM Code: TWRA code:		
# Crown w/acorns		Limb #	# Twig	# Twig w/acorns	Total acorns
0-20:		1			
21-40:		2			
41-60:		3			
61-80		4			
81-100		5			
		Total			
DBH:			Elevation		

Comments: ______________________________

Names: ______________________________

Instruction Reminders:

1. Turn map in with survey sheet.
2. Mark tree location on map if unable to find an appropriate tree at the site indicated on provided map.
3. Surveyed trees must be at least 12 inches (30.5 cm) dbh and not larger than 36 inches (75 cm).

Table B-6. Major hard mast trees of GRSM.

TWRA Code		Common Name	Scientific Name
		WHITE OAKS	
01	QRCALB	White Oak	Quercus alba
02	QRCPRN	Chestnut Oak	Quercus prinus
03	QRCSTL	Post Oak	Quercus stellata
04	QRCMHL	Chinkapin Oak	Quercus muehlenbergii
		RED OAKS	
20	QRCBR	Northern Red Oak	Quercus rubra
21	QRCFLC	Southern Red Oak	Quercus falcata
23	QRCCCC	Scarlet Oak	Quercus coccinea
24	QRCVLT	Black Oak	Quercus velutina
25	QRCMRL	Blackjack oak	Quercus marilandica
32	QRCIMB	Shingle Oak	Quercus imbricaria
34	QRCRED	Unidentified Red Oaks	
		HICKORIES	
40	CRY	Unidentified Hickory	
41	CRYCRD	Bitternut Hickory	Carya cordiformis
42	CRYTMN	Mockernut History	Carya tomentosa
44	CRYOVT	Shagbark Hickory	Carya ovata
45	CRYGLB	Pignut Hickory	Carya glabra
--	CRYOVL	Sweet Pignut Hickory	Carya ovalis
--	CRYPLL	Sand Hickory	Carya pallida
		WALNUT	
60	JGL	Unidentified Walnut	
61	JGLNGR	Black Walnut	Juglans nigra
62	JGLCNR	Butternut	Juglans cinerea
		BEECH	
70	FGSGRN	Beech	Fagus grandifolia

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